THE INTERNATIONAL

EXT-BOOK OF SURGERY

BY

AMERICAN AND BRITISH AUTHORS

EDITED BY

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VOLUME I

GENERAL AND OPERATIVE SURGERY

WITH 458 ILLUSTRATIONS IN THE TEXT, AND
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PREFACE.

In presenting a new work on surgery to the medical profession the editors feel that they need offer no apology for making an addition to the list of excellent works already in existence. Modern surgery is still in the transition stage of its development. The art and science of surgery are advancing rapidly, and the number of workers is now so great and so widely spread through the whole of the civilized world that there is certainly room for another work of reference which shall be untrammelled by many of the traditions of the past, and shall at the same time present with due discrimination the results of modern progress.

Their aim has been to produce a reliable text-book of surgery embodying a clear but succinct statement of our present knowledge of surgical pathology, symptomatology, and diagnosis, and such a detailed account of treatment as to form a reliable guide to modern practice. While not aiming at the merely novel, they have carefully omitted antiquated methods, and they hope that the reader will find in these pages only what is practically useful to-day.

The ever-widening field of surgery has been developed largely by special work, and this method of progress has made it practically impossible for one man to write authoritatively on the vast range of subjects embraced in a modern text-book of surgery. In order, therefore, to accomplish their object, the editors have sought the aid of men of wide experience and established reputation in the various departments of surgery, and they most gratefully acknowledge the very able assistance received from them. The editors have endeavored, by means of careful scrutiny of the manuscripts, to secure uniformity of standard and teaching.

The work is so arranged that Volume I. is devoted chiefly to

General Surgery, and Volume II. to the various branches of Sp
Surgery—a plan well adapted to the present needs of both the stu
and the practitioner.

It is with deep regret that the editors are obliged to record death of one of their contributors, Dr. John B. Hamilton of Chica

The editors take this opportunity to express their obligation Dr. F. B. Lund of Boston for his able assistance in the work of ed these volumes.

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GENERAL AND OPERATIVE SURGERY.

CHAPTER I.

SURGICAL BACTERIOLOGY.

A BRIEF STATEMENT OF THE ESSENTIALS IN SURGICAL BACTERIOLOGICAL PROCESSES.

General Principles.—Before entering upon the discussion of the technic to be employed in surgical bacteriological work, there are a few general considerations that should be emphasized. Of these, perhaps one of the most important is the fact that bacteria of any kind, pathogenic and non-pathogenic, do not pass off moist surfaces. The practical value of this observation lies in the teaching that floors, tables, and furniture in the operating-room should be cleansed with a moist towel, mop, or other utensil, the better to prevent the rising and dissemination of dust-particles, so often shown to be the carriers of the bacteria.

Structure and Classification.—The structure of the bacteria is simply cell-membrane and protoplasm, and they are not possessed of organs of digestion or of generation. Roughly speaking, they are classified, for medical purposes, as follows: Cells which have all diameters the same—the spherical forms, or the *micrococci;* those in which one diameter is longer than any of the others, and at the same time not curved—the bacilli; and those in which one diameter is longer than the others, and is more or less sharply curved—the spirilla. (This grouping is, of course, of the roughest, from a botanical point of view.) The *development* of the bacteria occurs in two ways: by transverse subdivision in one or more planes at the same time, and by spore-formation. The *micrococci* develop by transverse subdivision in one or more directions; if in one plane only, and if there is an incomplete separation of the two daughter-cells, a diplococcus is formed, and if this growth and incomplete separation continue in the same plane, a chain is produced—a *streptococcus;* if not in the same plane, but in irregular planes, a zoöglea mass is formed, whilst if the separation is complete, there results the grouping of the *staphylococcus.* If the development is in two planes at right angles to each other, four cells are produced from one mother-cell—a method of development of which the M. tetragenus is an example; and if this growth takes place in three planes at the same time, when incomplete separation occurs, as is usually the case, the sarcina is the result. The development of the bacilli is similar so far as it goes; that is to say, it occurs by transverse subdivision. Now, this subdivision is in one direction only, and that never in the line of the length of the rod. Subdivision, however, is not the only method of development of the bacilli. In certain conditions, usually those unfavorable to rapid growth, certain highly refractive bodies make their appearance, usually at the poles or the center of the rod, which then may disappear entirely,

leaving only these highly refractive and generally oval-shaped bodies, which are extremely resistant to destructive agencies. These bodies are *spores*, and form the resting and resisting stage of the development of many bacilli.

Whether the surgeon has to do with a process set up by a spore-bearing or a non-spore-bearing micro-organism may often be a matter of practical importance, as influencing the adaptation of means to an end in the measures necessary for securing sterilization of the field of operation or the secretions and material obtained from it. Spore-production has not been observed with certainty among the micrococci or among the spirilla—certainly not among the varieties that are sufficiently common in surgical affections to make them factors that must be reckoned with.

Lastly, the *spirilla* develop, so far as is known, by transverse subdivision only, and this division of the mother-cell occurs at the junction of two curves only, so that the young cells of the class of the spirilla often present the appearance of short curved rods—an appearance which very quickly disappears under favorable conditions of growth.

These *conditions of growth* are to be considered under food-supply, temperature, light, moisture, and gaseous surroundings.

The food-supply is obtained by the bacteria by the breaking up of the extremely complex organic substances that form the bodies of plants or animals dead, or which are excreted by them while still alive. Whilst it is true that the artificial food-supply of bacteria cannot imitate at all perfectly that which they find for themselves under natural conditions, the adaptability of many varieties renders it more possible to study them under artificial conditions than would otherwise be the case. In general, the bacteria require certain of the carbohydrates for their nutrition; and, for the study of the pathogenic varieties, the nearer their artificially prepared nutrient material approaches to that upon which they naturally thrive, the better will be the results. For this reason, preparations from fluids or tissues of the animal body are more advantageous for the study of the bacteria than are mixtures that must be made up more or less empirically.

Besides the necessity for a supply of certain amounts of carbon, hydrogen, nitrogen, etc., certain general conditions must be fulfilled to permit the development of the bacteria, pathogenic or otherwise. They must have a certain amount of moisture; for, whilst it is true that simple drying, even prolonged over a term of years, does not kill certain kinds of bacteria, especially those that produce spores, it is equally true that no development of these minute bodies will go on under a total absence of moisture. So, also, the presence or absence of certain gases has a marked influence upon the growth of certain kinds of bacteria. In the case of oxygen this influence is so marked that an attempt has been made to draw a sharp line of division between the *aërobic* (needing oxygen) and the *anaërobic* (requiring the absence of oxygen) bacteria. The latter division does not include many varieties that have been studied, or, indeed, whose existence has been revealed to us by our present means of observation, especially in surgery.

Temperature is another of the general conditions that must be reckoned with to secure proper conditions for the growth of the bacteria. By far the larger part of them flourish well at a temperature of between 20° and 25° C.; those that produce pathogenic change in living tissue must be able to flourish at a higher degree of heat than this, and most of them will grow best at 37°–38° C. Above the highest and below the lowest of these limits practically no growth occurs. Some observations record development as high as 70° C. and as low as 5° C., but no indication of development of any of the pathogenic bacteria has been obtained at or near either of these points. An important practical conclusion to be drawn from our knowledge of the effect of temperature on the vitality of the bacteria is, on the one hand, that cold does not destroy them, even when applied under conditions entirely beyond those that occur in actual life. Koch's experiment of placing the cholera spirillum at −32° C. without affecting its developing powers when brought back to normal conditions is a case in point. On the other hand, a very moderate degree of heat is sufficient to kill most bacteria, very few of them being able to withstand so low a temperature as 57° C. if applied for a sufficient length of time (the destruction of spores, of course, requires a much higher degree of heat).

Light is another of the general conditions that has an influence upon the growth of bacteria, and it has been shown that the effect of direct sunlight is apparently very hurtful to the vitality of many kinds of bacteria. It is certain that the thickness of the medium in which the bacteria are has much to do with the intensity of the effect of sunlight upon them; and it is still an open question whether much of the effect of sunlight be not due to the heat of the rays and their drying effect (depriving the bacteria of moisture).

The movements of bacteria, when they are present at all, are affected in many ways: of course, by extremes of heat and cold, which must more or less influence their vitality; but of special importance is the *chemiotactic* influence of certain salts and other materials, manifested by an attractive or repellent action toward the bacterial cells. This *positive* or *negative* chemiotaxis is of the same nature as that seen in the case of the cells of the tissues, leukocytes and others, in response to the irritant action of chemicals, injuries, or even of the bacteria. Although disease is all that concerns us here, the bacteria are active in many other processes. Properly looked at, disease is but another name for a perfectly normal function, the bacteria producing the disease doing so simply because they find in the tissues in which they grow the nutrition necessary for that growth. This nutrition they secure by breaking up the complex materials of which the tissues are composed or upon which they are fed. Infectious diseases and their products are therefore really the waste results of bacterial growth.

The methods by which the bacteria produce their results in the body, very briefly stated, are as follows:

It was formerly supposed that the results seen in bacterial disease were due entirely to the direct action of the bacteria themselves. This position, however, very quickly became untenable, for innumerable phenomena were observed that were inexplicable upon this ground, if

the bacteria themselves were to be looked upon as anything but accompaniments of the disease-process. Other explanations were therefore sought and obtained. The influence of the bacterial cell itself in the production of morbid phenomena is very slight. In a few cases there is an actual mechanical action exerted by the overwhelming of special localities by masses of cells, and a resultant interference with the function of the part, or possibly a destruction due to pressure. This, however, is not often seen. There occurs also an absorption by the bacteria of nutrition meant for the tissue-cells, and in this way a destruction of these tissue-cells that might be spoken of as starvation. Neither of

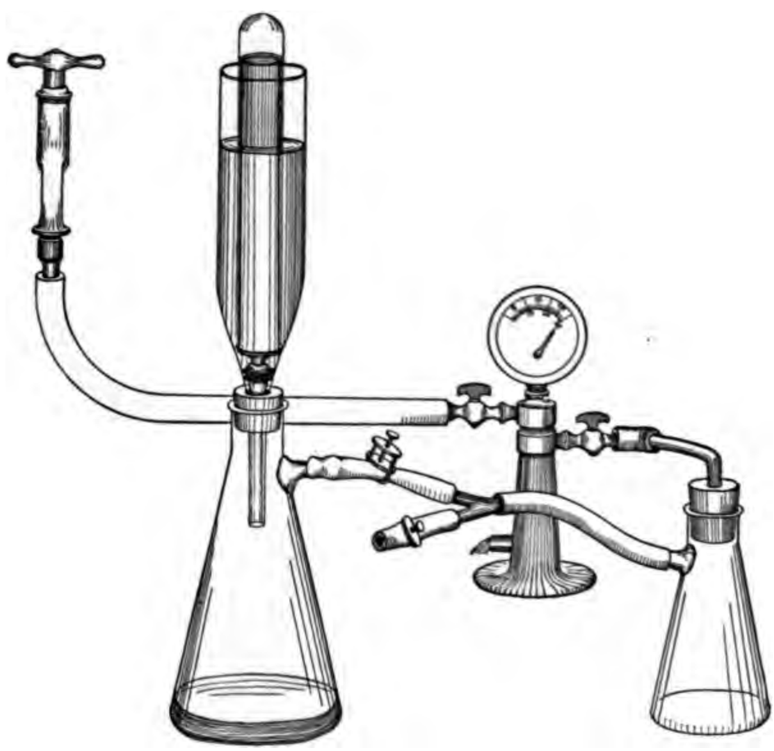


FIG. 1.—Apparatus for using Chamberland filter, with glass tube inverted over filter, acting by capillary attraction, so that the whole filtering surface may be in use (as suggested by Dr. J. L. Goodale).

these actions, however, is sufficient to explain by far the vast majority of the phenomena seen as the result of bacterial growth. The general process may be made clear by the supposition that the bacteria, during their development, take from the complex compounds in their neighborhood certain chemical elements that are necessary for their own nutrition. Thus there are left other elements in a condition of unstable equilibrium. These elements combine in the ways necessary to satisfy this unstable condition. As a result of this combination new compounds are formed, some more simple, others more complex than the originals. Among these new compounds there occur, in many instances

of bacterial growth, some that are extremely hurtful to the tissues in which they are found. These are the toxins of which so much is now said, and it is to these toxins and their action upon the living tissues that are due most of the harmful results that are seen to follow bacterial growth.

The occurrence of *variation* among bacteria has been a matter of much discussion. The general conclusion seems now to be justifiable that only minor variations occur, and that there is a definite type of structure and of function to which each bacterium tends to return.

Methods of Cultivation.—For a full description of these methods the student must turn to the larger text-books.

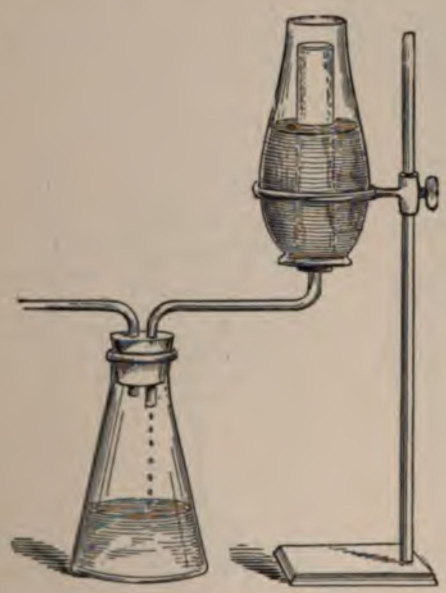


FIG. 2.—Chamberland filter in lamp-chimney for filtering small quantities of fluid.

As preliminary to the obtaining of a pure culture, the vessels containing the nutrient media, and these media themselves, must be completely freed from any form of bacterium. This is **sterilization,** and may be secured by the use of heat in its various forms, by the use of chemicals, and, in the case of fluids, by filtration.

Heat may be applied first by direct exposure to the naked flame, possible with knives, scissors, platinum wires, etc., and for burning infectious material. Second, by the use of heated air, as in the case of the hot-air chamber, in which the temperature may be raised to a high degree by the external application of the heat; this method is applicable to the sterilization of glassware, instruments, etc. Third, moist heat, either direct boiling of fluids in suitable vessels (which is not satisfactory where spore-bearing bacteria are to be destroyed), or by the use of steam under varying degrees of pressure. Steam-heat under pressure is the most effective means known for the destruction of bacteria. Its action is distinctly more rapid, penetrating, and certain than any other, and for its use many different forms of apparatus, all expensive, have been devised.

Filtration through unglazed porcelain (the Chamberland filter) or through tubes of infusorial earth is employed as a means for sterilizing fluids whose composition is likely to be changed by the application of heat (Figs. 1 and 2). Moist heat is used for the sterilization of culture-media, and for the treatment of infected bedding, clothing, etc. which may be

desired for use again. Filtration finds its application in the separation of bacteria fi fluids in which the products of bacterial growth are to be submitted to further study.

Chemicals.—Sterilization by the use of chemicals is possible only in bacteriological te nic, where the instruments or glassware so treated may be subjected to thorough wash before being again used. But chemicals find an extremely useful place in the sterilizat of discharges of various kinds, instruments, vessels, old dressings, etc.

In all cases in which it is desired to secure sterilization, and to keep the objects sterili free from further contamination by living forms, means to this end must be taken. Thi almost universally found in the closing of the neck of the containing vessel with cott wool. This cotton-wool stopper is not meant to act as a cork, to prevent entirely the trance of air; it needs merely to be a *filter*, permitting free entrance of air, but filtering the bacteria and moulds. Used in this way, it serves as a perfect protection against entrance of the bacteria; at the same time, it is not a permanent protection against moul which after a time will grow down through the interstices of the cotton, their spores fin dropping upon the nutrient medium below. This may be guarded against by sprinklin

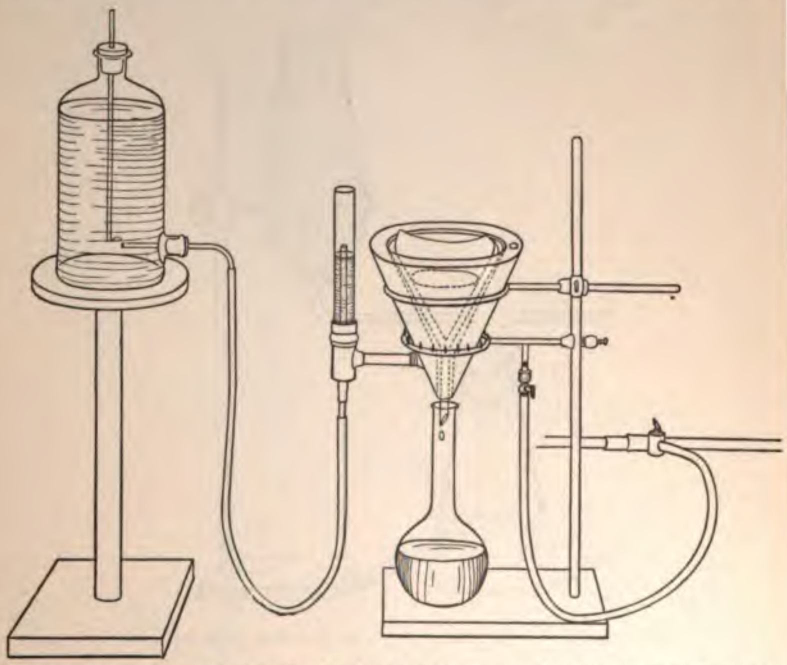


FIG. 3.—Showing the application of a Mariotte's flask to a hot filter for keeping the water at constant level.

few drops of solution of corrosive sublimate upon the upper surface of the cotton, and co ering the whole with a rubber cap, the latter serving also to prevent the evaporation of tl moisture that would otherwise take place.

In general, sterilization by dry heat is completed by exposure for an hour to a temper ture of 180° C. Boiling for five minutes is sufficient to kill non-spore-bearing bacteri Steam at 100° C. for one and a half hours is enough to sterilize any nutrient medium; bu as gelatin will not stand this amount of heat without losing its power of solidifying on coo ing, intermittent sterilization—twenty minutes at a time on three successive days—must b resorted to where this material is concerned. Steam under pressure at 120° C. (thirt pounds) for fifteen minutes is sufficient to destroy all spores or bacteria. The special pr cautions to be taken in this form of sterilization (with the autoclave) may be learned fro the persons supplying the apparatus.

Nutrient Media.—The general principles to be observed in the preparation of thes media is that they must resemble as closely as possible those upon which the bacteria ord narily flourish. By far the most common of the nutrient media employed is *nutrient gelatin* spoken of as "gelatin." This consists of—

Meat-water,	1000 c.c. ;
Sodium chlorid,	5 gms. (0.5 per cent.) ;
Peptone, dry (Witte),	10 gms. (1 per cent.) ;
Gelatin (best French gold label),	100 gms. (10 per cent.).

Mix, warm until all gelatin is dissolved, and neutralize carefully with a saturated solution of sodium carbonate. Filter, while warm (Fig. 3), through filter-paper, and place in quantities of about 10 c.c. in test-tubes plugged with cotton-wool and previously sterilized by dry heat (Fig. 4). Sterilize by subjecting to steam at 100° C. for twenty minutes upon three successive days. Sometimes the mixture does not come through clear at first. This may be due to dirt in the pores of the filter-paper or to incomplete neutralization; sometimes, also, it does not come clear after these points have been looked after, when it may be cleared by adding the white of one or two eggs, heating, and refiltering. Sometimes the gelatin becomes cloudy after being placed in the test-tubes. This may be due to a trace of acid that is left on the sides of the tubes as they come from the factory. The danger from this cause may be abolished by thoroughly washing the test-tubes in hot water before using them.

Meat-water, which is the basis of many other media besides nutrient gelatin, is prepared as follows:

Finely-chopped lean meat,	500 gms. ;
Water (pure, but not of necessity distilled),	1000 c.c.

Mix, and let stand in a cool place (in summer in the ice-chest) for twenty-four hours, stirring occasionally. Strain through coarse cloth and under pressure, to extract all the moisture possible. If the bulk is not 1000 c.c. of watery extract, add enough water to bring it up to that amount. Boil in a water-bath for an hour; filter through coarse filter-paper. From this meat-water may be made the nutrient gelatin spoken of above, and ***nutrient bouillon***, which consists of—

Meat-water,	1000 c.c. ;
Sodium chlorid,	5 c.c. (0.5 per cent.) ;
Peptone, dry (Witte),	10 c.c. (1 per cent.).

Mix. Neutralize very carefully with a saturated solution of sodium carbonate, added drop by drop as the line is approached, until red litmus is turned slightly blue, and blue litmus is not turned red (to avoid the amphoteric reaction). This bouillon may be kept in bulk in flasks or be placed in test-tubes, and sterilized by steam at 100° C. for an hour and a half, or by steam under pressure.

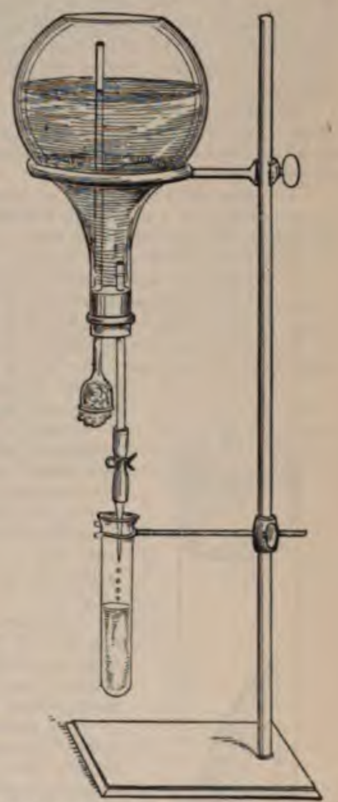


FIG. 4.—Apparatus for filling test-tubes.

For the study of bacteria at the temperature of the body there is often needed a medium that is more easy of preparation than blood-serum. Such a medium is found in nutrient *agar-agar*. This is prepared precisely as is nutrient gelatin, excepting that in the place of the 10 per cent. of gelatin there is added from 1 to 1.5 per cent. of agar-agar. The mixture is difficult to make clear, but this end may be reached by the addition of the white of an egg before filtering, or by straining two or more times through filter-paper. To facilitate filtering, the whole apparatus may be placed in the steam sterilizer, or in that illustrated in Fig. 3.

Glucose media are often useful for special purposes, and are prepared by adding, usually, 1 per cent. of glucose to the different media already spoken of.

Whilst these mixtures are necessary adjuncts to the study of the biological characteristics of all bacteria, certain of these characteristics are not so well observed, and some of them are not seen at all, unless a solid albuminous material, approaching the conditions found in the tissues, be employed. This is in no way so well secured as by the use of *blood-serum*. This furnishes the nearest approach to the elements found in the living tissues for the nutrition of bacteria, and was first introduced by Koch for the study of the bacillus of tuberculosis.

The blood is collected under as nearly as possible aseptic conditions, is allowed to clot in a cool place, and in handling is shaken as little as possible. At the end of twenty-four or forty-eight hours the serum is drawn off, placed in sterile test-tubes, and sterilized at a temperature of 57° C. for an hour each day during six days. If it be desired to use the serum in its fluid condition, it is now ready; but if, as is usually the case, it is desired to use it as a solid nutrient medium, it may be solidified, after this sterilization, by being raised to 64° or 66° C. for several hours until it has solidified; or it may be solidified immediately after being placed in the test-tubes by being placed in an Arnold sterilizer, in which case the coagulation and the sterilization may be carried on at the same time. This rapid coagulation naturally makes the blood-serum opaque. It may be made to retain its translucency by taking advantage of a known physiological fact, and adding, before the sterilization, from $\frac{1}{10}$ to $\frac{1}{4}$ of 1 per cent. of a caustic alkali—either sodic hydrate or potassium hydrate—the amount to be used depending upon the kind of animal from which the serum was drawn. The addition of this amount of alkali will enable the rapid method of sterilization of blood-serum to be adopted, and at the same time will give as a result a solid medium of a very considerable degree of translucency.

Blood-serum may be used plain or, as is now very common, in the form of *Löffler's blood-serum mixture*, consisting, in the original, of 3 parts of calves' or lambs' blood-serum, to which has been added 1 part of bouillon containing 1 per cent. of glucose, sterilized as for blood-serum.

The difficulties in the way of keeping up the virulence of the streptococci have led to the suggestion of a number of different media for this particular purpose, and of these, those of Marmorek seem to be the best. His media are made by mixing—

1. Human blood-serum 2 parts, nutrient bouillon 1 part.
2. Pleuritic or ascitic serum 1 part, bouillon 2 parts.
3. Ass- or mule-serum 2 parts, bouillon 1 part.
4. Horse-serum 2 parts, bouillon 1 part.

Dunham's peptone solution, useful for studying the indol reaction, is prepared by adding 1 per cent. dry peptone (the best is Witte's) and 0.5 per cent. sodium chlorid to distilled water. Filter after the solids are dissolved, place in sterilized test-tubes, and sterilize by steam heat.

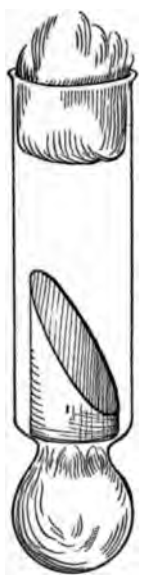


FIG. 5.—Test-tube with constriction at bottom for supporting potato-cultures above the water of condensation.

Certain characteristics of bacteria are best shown upon starch-containing materials, and this starch-containing nutrient medium is best found in sterilized potato. The potatoes may be prepared for use most easily by cutting out cylinders with an ordinary apple-corer, cutting the cylinder into two wedge-shaped portions, and placing them in sterilized tubes with some form of support (small pieces of glass rod), below the potato, to keep it from the bottom of the tube, and sterilizing the whole for at least an hour in the steam sterilizer (Fig. 5).

Most material to be studied bacteriologically contains more than one kind of bacterium. Some method for separating these varieties must therefore be adopted. By far the most common method in use is that of plate-culture, either according to the original method of Koch (using three or more glass plates), or a more common method of using three or more shallow double dishes, the so-called Petri dishes. A method of making plate-cultures is as follows: Melt three or more tubes of nutrient gelatin; introduce into the first tube a small quantity of the material to be examined, and mix it thoroughly without shaking, so as to prevent the formation of air-bubbles. From this first dilution transfer two platinum loopfuls of the mixture to a second tube, and mix thoroughly. From this second tube transfer again two loopfuls to a third tube, and mix thoroughly. This dilution may be carried further if there is reason to suppose the existence of a large number of bacteria in the original material, or a number of rapidly growing liquefying bacteria. The dilutions are then poured so as to be distributed evenly over the bottom of the lower of the Petri dishes, are covered with the upper one, the gelatin is allowed to harden, and the cultures are set aside for further observation.

Esmarch's roll-cultures are made in precisely the same way, so far as the mixing in the gelatin is concerned; instead, however, of pouring the dilutions either upon glass plates or in the Petri dishes, the tubes themselves are laid almost flat upon a piece of ice and are rapidly revolved. The gelatin mixture solidifies upon the side of the tubes themselves, and plate-cultures are formed in the tubes. Plate-cultures may be made with nutrient agar as with nutrient gelatin, except that care must be taken that the melted agar is not so hot as to kill the bacteria sought for. These cultures are of value when it

is desired to study bacteria at the temperature of the body. So, also, a separation of bacteria may be secured with a good deal of accuracy by spreading the material to be examined upon a surface of nutrient agar or nutrient blood-serum, or upon the surface of blood-serum plates. This spreading is done by dipping the platinum wire (Fig. 6) into the infected material and drawing it, in successive parallel lines, over the surface of the material as

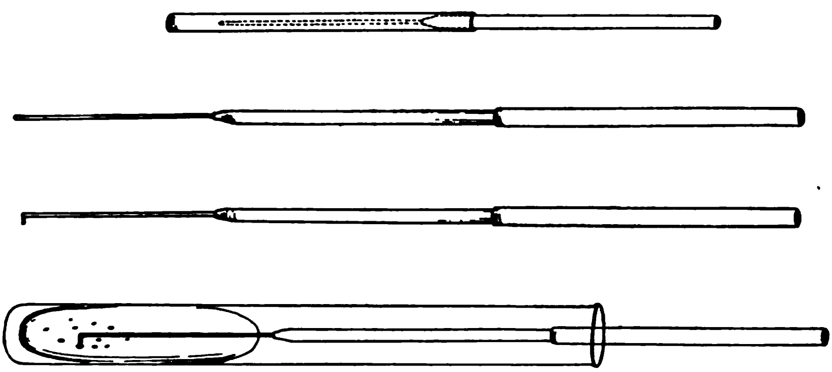


FIG. 6.—Platinum wire swaged into brass wire, and reversible for transportation (as devised by Dr. J. H. McCollom). *a.* Closed. *b.* Open. *c.* The same with end bent at right angles, for picking up colonies in test-tube. *d.* The same in operation.

many times as may be possible. Sometimes it is necessary to separate pathogenic bacteria by the inoculation of animals with the mixture of bacteria, and, when a particular disease appears, obtain pure cultures from the tissues of the animal so inoculated. Occasionally also the separation is obtained by the killing of non-spore-bearing forms by heat.

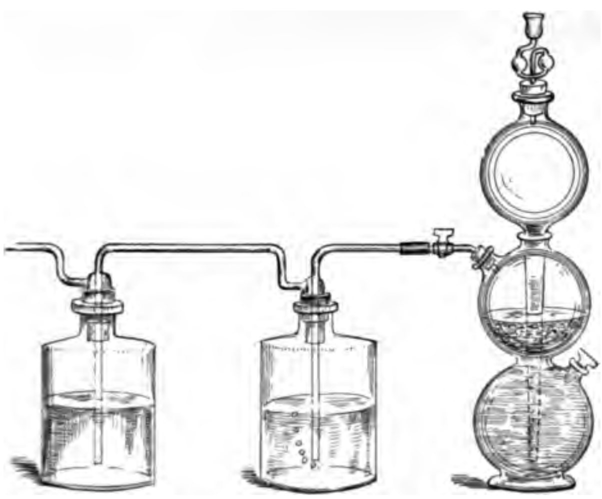


FIG. 7.—Kipp's apparatus for producing hydrogen, with wash-bottles attached.

Certain of the bacteria grow only in the absence of oxygen. In such cases it is necessary to take measures for the exclusion of the oxygen. This may be done by substituting for air an atmosphere of hydrogen—the common method adopted (Fig. 7); by covering the ordinary needle-culture in gelatin or agar with a layer of sterile oil or an added amount of the same nutrient medium; or by a fermentation-tube, a modified form of which is shown below (Fig. 8).

Hanging-drop cultures, frequently necessary for the purpose of studying bacteria alive, consist simply of a cell-slide over which is placed a cover-glass, on the under surface of which is suspended a drop of nutrient fluid containing some of the bacteria it is desired to examine.

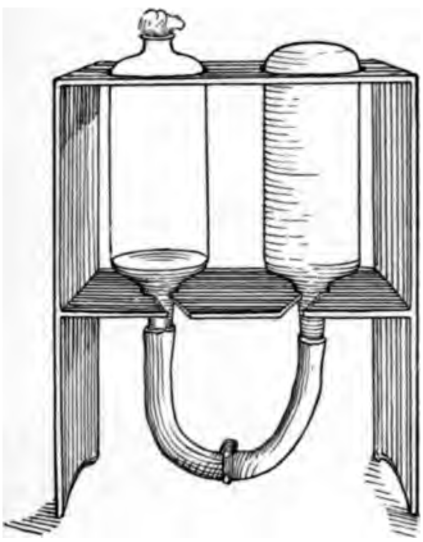


FIG. 8.—A method for carrying on anaërobic cultures and measuring gas-production (as devised by Prof. Theobald Smith).

The filtration of cultures—that is, the removal of all bacteria from fluids in which they have grown—is accomplished by one of the many forms of the Chamberland filter, through tubes of unglazed porcelain or infusorial earth.

Cultures are usually observed at a temperature of from 20° to 22° C., which is represented by the average temperature of the ordinary room; or they are studied at the temperature of the body, which is approximately 37.5° C. For the latter purpose a special warm chamber is necessary, of which there is a large number, the general principles of them all being the same.

The general methods for the study of the bacteria, so far as they differ from those of ordinary histological work, require, in the first place, a good microscope, which should include coarse and fine adjustment, with a homogeneous immersion lens, and a substage condenser. The bacteria may be examined either stained or unstained, in cover-glass preparations and in sections. When bacteria are examined unstained, the hanging-drop method is useful; for stained preparations recourse must be had to "cover-glass preparations." Perfectly clean cover-glasses are used, and a minute portion of the material containing the bacteria is placed upon one of them and spread in as thin a layer as possible, either by means of a platinum wire, or by placing a second cover-glass upon the first, pressing the two together very gently, and drawing them apart in as nearly as may be the same plane. The material is allowed to dry in the air, and the cover-glasses are then passed through the flame of a Bunsen burner three times, so as to fix the film on the surface of the cover-glass and prevent its being washed off. In the case of blood this fixation is best accomplished by placing the cover-glasses in a hot-air chamber at 120° C. for an hour, or by immersion in a strong solution of corrosive sublimate for two or three minutes; the cover-glasses are then washed and dried. Sometimes also, if the structure of the tissue-cell is desired, "corrosive" films may be substituted for the dry films. These films are prepared by placing them, while still wet, in a saturated solution of perchlorid of mercury in 0.75 per cent. of sodium chlorid for five minutes, then for half an hour in 0.75 per cent. sodium-chlorid solution to wash out the corrosive sublimate; they are then washed in alcohol, at first dilute, then stronger, a few minutes in each; after this they may be stained and examined (Muir and Ritchie).

For bacteriological purposes tissues are best hardened in absolute alcohol. The material is cut into pieces from 1 to 2 c.c. in size, and these are placed in absolute alcohol, which is to be changed on successive days three times; the tissue is then ready for cutting with any of the apparatuses for cutting sections. Sections may also be cut from fresh material with the freezing microtome. Hardened tissues may be fixed on blocks with a few drops of celloidin or with glycerin jelly (Fig. 9). In examining bacteria in the tissues the object is to secure sections as thin as possible, not covering very large areas.

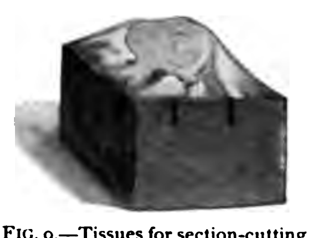


FIG. 9.—Tissues for section-cutting mounted on fiber blocks; stuck on with celloidin (as suggested by Dr. Henry Jackson).

Staining.—The staining of bacteria is almost a science by itself, and it has only been since the introduction of the anilin dyes that a great advance in our knowledge of the bacterial reactions has been made. There are a great number of these dyes, but only a few have been generally adopted for ordinary bacteriological work. Of these, there are the two classes, the basic and the acid dyes. Of the basic stains, those

most commonly employed are the following: Gentian violet, which stains very rapidly, and easily over-stains; methyl violet, with the same peculiarities to a less degree; fuchsin, which stains more slowly, does not easily over-stain, and is more permanent than the two others; methylene blue, which stains more slowly, almost never over-stains, and is extremely lasting; vesuvin, or Bismarck brown, which gives a brown stain that is not used much now. Its usefulness lies in the fact that preparations stained with it are peculiarly well adapted to photography; but since the introduction of orthochromatic plates the necessity for special staining of the bacteria for photography has practically disappeared. These are the common basic dyes that are employed in the study of bacteria. They are peculiarly fitted for the purpose, for the reason that they have a special affinity for the staining of the cell-nuclei of the tissues and of the bacteria.

The acid dyes commonly used are eosin, safranin, and picric acid. These dyes are employed for contrast-stains because they have an especial affinity for cell-protoplasm and intercellular substances, and are spoken of as diffuse stains. The variation in anilin dyes, not only in name but in chemical composition, makes it of importance that different observers should use the same dye, and this uniformity of stains is to be obtained, apparently, only by employing those prepared by Grübler of Leipsic. It is to be remarked also that all anilin colors degenerate more or less rapidly after the original package is opened, so that it is advisable to procure small amounts at a time. So, also, it is well to remember that all solutions of these dyes should be freshly prepared, saturated alcoholic solutions being the only ones that can be relied upon to keep for any length of time. These saturated alcoholic solutions may be used as stock solutions from which all the various staining mixtures may be prepared.

The first and most generally used of these staining mixtures is the *dilute alcoholic solution*, consisting of 1 part of the strong alcoholic solution filtered into 2 parts of distilled water.

The staining of cover-glass preparations may be accomplished either by floating the cover-glasses on the surface of the fluid for a few minutes, or by flowing the cover-glass itself, held in forceps, with a few drops of the stain. After exposure to the reagent for a few moments—on the average about five minutes—the cover-glass is to be thoroughly washed, dried, and then mounted in a drop of xylol balsam. The xylol balsam must be used in bacteriological work, for the reason that other solvents of Canada balsam dissolve the coloring matter from the bacteria more than is conducive to the best results.

Frequently bacteria come under observation that require special stains, but for the general staining of cover-glass preparations for the simple determination of the presence or absence of bacteria a saturated watery solution of methylene blue will be found to be the best to begin with.

Occasionally it is necessary to use mordants for the purpose of more intensely staining the bacteria. The use of mordants usually makes necessary the after-employment of some decolorizing agent to take away the intense staining from the tissues and leave the bacteria more prominent. The carbolic acid in the carbol-fuchsin mixture and the anilin-oil mixtures are examples of the use of mordants; so also are the alkalies used in the preparation of certain stains like caustic potash in the Löffler's solution, the use of heat, and the prolonged application of the ordinary staining fluid. As decolorizing agents the mineral acids are the strongest, vegetable acids, such as acetic acid, are next, alcohol next, and water last. For sections, dehydration and clearing are very important. Dehydration is accomplished with absolute alcohol, and clearing is attained by means of xylol, which is the cheapest, or by oil of cedar, which is the best—not with the ordinary clearing reagents, such as oil of cloves, because the latter decolorizes too much the specimen stained with the anilin colors.

Of the general methods used for staining, other than the single dyes, a few of the more common are these:

(1) *Löffler's alkaline methylene blue*, which consists of a saturated solution of methylene blue in alcohol, 30 parts, a solution of potassium hydrate in distilled water (1 : 10,000) 100 parts.

Sections may be stained in this mixture for from fifteen minutes to several hours; they are then to be decolorized with ½ to 1 per cent. acetic acid, washed in water, dehydrated in alcohol or anilin oil, cleared in xylol, and mounted. *Cover-glass* preparations may be stained in from five minutes to half an hour in the cold.

(2) *Kühne's Methylene Blue.*—Methylene blue 1.5 grams; absolute alcohol 10 c.c.; carbolic-acid solution (1 : 20) 100 c.c. This to be used, and the decolorization carried out precisely as with the preceding; or the decolorizing may be accomplished with very dilute hydrochloric acid—2 to 3 drops in a watch-glassful of water.

(3) *The anilin-water mixtures*, consisting of a saturated alcoholic solution of gentian violet, methyl violet, or fuchsin 10 parts, absolute alcohol 11 parts, anilin-water 100 parts. The anilin-water is simply a saturated solution of anilin oil in water, and is made by shaking up about 1 part of anilin oil to 20 parts of water and filtering carefully. These anilin-water mixtures are unstable, and are to be made fresh as often as once in every few days.

Carbol-fuchsin is prepared of basic fuchsin 1 part, absolute alcohol 10 parts, n of carbolic acid (1 : 20) 100 parts. This is a very strong stain, and under ordir ons one half to one minute is sufficient for staining cover-glasses. It is so strong it does not find any useful application in the staining of sections.

Gram's method of staining is a useful one, depending upon the decolorizing action the so-called Gram's mixture, consisting of resublimated iodin 1 part, potassium iodi parts, distilled water 3 parts. The action of this solution upon tissues containing bact is a special one, in that it removes the first stain from the tissues and from some bacteria, not others; so that, as in the case of the gonococcus, this method of staining furnishes a l toward a differential diagnosis. At the same time the action of the iodin solution upon bacteria does not seem to be a true decolorizing action, although it is difficult to say preci what it is.

A method of applying Gram's method is to stain the preparation in the anilin-oil gent violet mixture for about five minutes, and wash in water; then transfer to Gram's solu until the color becomes a purplish black (generally from thirty seconds to a minute is cient); decolorize with absolute alcohol until the black color has entirely disappeared the preparation is at the most of a very light violet color; dehydrate; completely cl then mount. Of course, in the case of cover-glass preparations the specimen is m washed in water, dried, and mounted.

Spore-staining.—Sometimes it is of advantage to stain spores that under ordinary cc tions do not take the coloring matter. An effective method is first to use the carbol-fuc stain, heating over the flame of a Bunsen burner for from fifteen to twenty minutes; decolorize with 1 per cent. sulphuric acid in water for a few seconds only; wash in wa contrast stain with saturated watery methylene blue for 15 to 30 seconds; wash careful water; dry and mount.

The *staining of flagella* is difficult, but as this has also been used for purposes of diffe tial diagnosis, a brief statement of the method may not be inappropriate here.

The first and best method is that of Löffler. In all cases twenty-four-hour cultures agar should be used; the cover-glass should be thoroughly cleaned before use; and preparation upon the cover-glass should consist of the minutest possible portion of the ture, diluted as much as may be in a drop of water.

Löffler's method is as follows: There must be two solutions.

a. The mordant. Add to 10 c.c. of a 20 per cent. solution of tannin in water as drops of a saturated solution of ferrous sulphate in water as will give the whole fluid a violet tint. To this add 3 to 4 c.c. of a solution made by boiling 1 gram of logwood 8 c.c. of water (after boiling, filter and add enough water to bring up to 9 c.c.). The ture of the tannin solution with the logwood solution is of a dirty, dark violet color, if too much logwood solution be added, particles are precipitated which make the fluid less as a mordant. This mordant should be made fresh each time it is used, althougl addition of 4 to 5 c.c. of a 1 : 20 carbolic-acid solution makes it more stable without inj its properties.

b. The stain. To 100 c.c. of a filtered saturated solution of anilin oil in water 1 c.c. of a 1 per cent. solution of sodic hydrate, which makes the mixture faintly alka To this add 4 to 5 grams of methyl violet, methylene blue, or fuchsin-crystals, and thoroughly.

When a preparation is to be stained, flood the cover-glass, held in forceps, with as of the filtered mordant as possible; heat carefully above the flame until the steam begi rise—for about a minute; wash well in distilled water until every trace of the mo appears to be gone. If necessary, wash with absolute alcohol until only the film itsel pears to be tinted violet by the mordant; filter a few drops of the stain on to the cover-g again heat until the steam rises, and leave in the warm stain for one minute; wash w distilled water; dry, and mount in xylol balsam.

Procedure in Bacteriological Examinations.—In surg bacteriology, as in any other, a definite routine is the best to adop the examination not only of the materials submitted, but at the of operation.

In the case of materials submitted for examination, there mus always (1) a microscopic examination; (2) an effort to isolate the teria presented; and (3) an attempt at an identification.

Materials must be protected, so far as possible, from contamina by extraneous bacteria, and nothing must be done that will kill bacteria that may be contained in the material. Of course, there i cluded the necessity for obtaining the material as soon as possible

its removal from its natural surroundings. If the material to be examined be fluid, and it is necessary to transfer it for any distance, it may be received in sterile pipets, which may be drawn into capillary ends and sealed in the flame, or which may be plugged with cotton in one end, whilst the other passes through the cotton stopper of a sterile test-tube. If the fluids or tissue-juices are to be examined at once, this may be done by transferring a small portion, by means of sterile platinum wires, or pledgets of cotton wound upon the roughened ends of ordinary wire, to the nutrient medium that is to be used and the cover-glass that is to be examined microscopically. Tissues should be obtained, if possible, with the organ to which they belong, whole. These organs may be examined by searing the surface with a red-hot knife or cautery, making an incision through this seared surface with a fresh knife, and from these freshly exposed surfaces making cover-glass and plate-cultures; or the surfaces may be sterilized by thoroughly soaking in 1 : 1000 corrosive-sublimate solution, drying, and making an incision with a sterile knife, which incision may be deepened by tearing, thus obtaining a perfectly uncontaminated surface.

The routine procedure for the bacteriological examination of material in the case of a discharge is first to make a number of cover-glass preparations, which may be stained by Gram's method and with several other ordinary stains; next, plate-cultures should be made in nutrient gelatin, in nutrient agar, and on blood-serum, and the development should be carefully studied.

A shorter method of making plate-cultures is to pass the needle, dipped in the material, in three successive parallel lines over the surface of the blood-serum or nutrient agar, and keep these cultures at blood temperature. This method, however, is not as perfect as those first spoken of.

As soon as the colonies appear upon the plate-culture, they should be examined with a low-power lens. In the case of those that cannot be identified by this examination, further study must be carried on. The student should note first the microscopic appearance, including the form, size, arrangement, and the staining reactions; whether the organism is motile; whether it produces spores; then the characteristics of its growth—how it appears in its development upon gelatin, in needle-culture; the rate and form of growth; the presence or absence of liquefaction; whether or not it produces gas or odor; whether or not it produces acid; and the characteristics of the colonies upon plate-culture; so also the characteristics of the growth upon agar at a temperature of 37° C. in bouillon, on blood-serum, on potato, milk, litmus media, sugar media, and peptone solution. The rapidity of growth should also be noted; whether or not the bacterium produces spores or pigment; its staining reaction; and the result of inoculation experiments in animals.

Practically all inoculation experiments are performed by means of a hypodermic syringe, and thus far no syringe has given better satisfaction than the ordinary "Koch" syringe (Fig. 10). Methods of inoculation may be either (1) by simple scarification of the skin and a rubbing in of the infectious material; (2) by subcutaneous injection, preferably near the root of the tail or between the shoulders; (3) by

intraperitoneal injection; (4) by intravenous injection, for which purpose the vein of the ear is most commonly used; or (5) by injection into special regions, such as the anterior chamber of the eye, the tissue of the lung, etc. Autopsies on animals, dead or killed after inoculation,

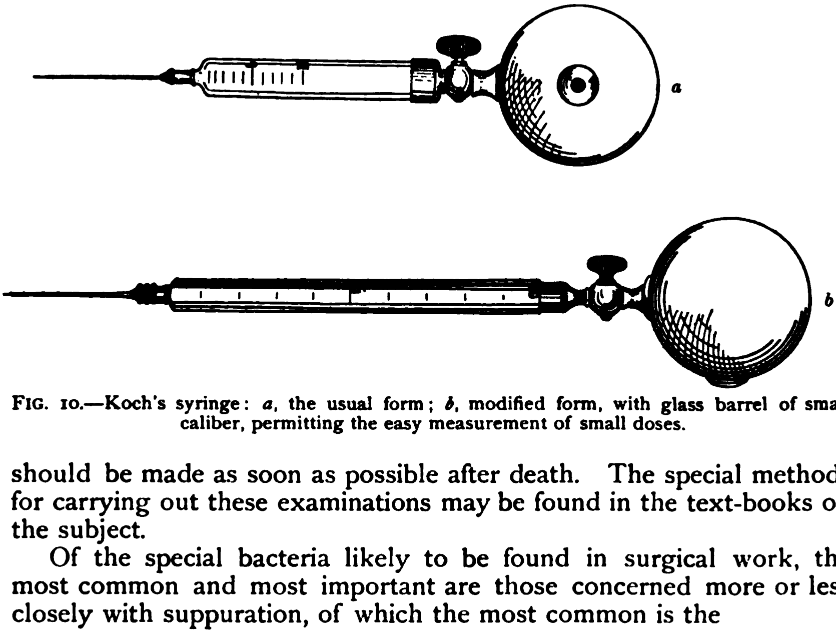


FIG. 10.—Koch's syringe: *a*, the usual form; *b*, modified form, with glass barrel of small caliber, permitting the easy measurement of small doses.

should be made as soon as possible after death. The special methods for carrying out these examinations may be found in the text-books on the subject.

Of the special bacteria likely to be found in surgical work, the most common and most important are those concerned more or less closely with suppuration, of which the most common is the

Staphylococcus pyogenes aureus, a micrococcus of irregular size, of an average diameter of 0.9 μ, arranged irregularly in masses (Plate 1, Fig. 1).

This bacterium, which is non-motile, grows on gelatin plates in minute colonies, apparent under a low power of the microscope after twenty-four hours, granulated on the surface, and of a brownish color. The colonies gradually become visible to the naked eye as whitish-yellow points, which later become more distinctly golden yellow. Liquefaction of the gelatin occurs around them, and a funnel-shaped depression appears, at the bottom of which are the colonies. In needle-cultures in gelatin the line of development appears along the needle-track on the day after inoculation, and on the second or third day the beginning of liquefaction may be noted at the upper portion. The liquefaction progresses slowly at the lower portion of the culture, more rapidly at the upper part; as it increases, the main portion of the colony falls to the bottom as a flocculent deposit which takes on a golden-yellow color, whilst the liquefied portion remains turbid; finally, in from one to two weeks, the gelatin becomes entirely liquefied out to the wall of the tube. On agar (Plate 2, Fig. 1) the colonies develop along the needle-track as an abundant, moist, shining growth, which is well marked after twenty-four hours at the temperature of the body. It later takes on the golden-yellow color, which may be well marked at the end of forty-eight hours. On potato it grows well, producing an abundant layer that also assumes a golden-yellow color. In bouillon it produces a uniform cloudiness, which later sinks to the bottom, with a brownish-yellow color. It coagulates milk, produces an acid reaction in the various media, does not produce spores, although it retains its vitality in old cultures for a considerable length of time, and requires rather a higher temperature for its destruction than most non-spore-bearing bacteria (according to Lubbert, needing a temperature of 80° C. for half an hour). It stains readily with any of the anilin colors, and by Gram's method.

Pathogenic Properties.—Injections of small amounts of pure culture are usually not followed by any results; but large amounts, or intravenous or intra-abdominal injections, are usually followed by fatal results in rabbits or guinea-pigs in a few days, with minute abscess-formation in the kidneys especially.

The **Staphylococcus pyogenes albus** is a micrococcus less virulent than the pre-

FIG. 1.—Staphylococcus pyogenes aureus; pure culture on blood serum after tw four hours at 22° C.; fuchsin; camera lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 2.—Streptococcus pyogenes; bouillon culture, twenty-four hours; Löffler's m lene blue; camera lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 3.—Bacillus coli communis; agar culture, twenty-four hours old, at 22° C.; ca lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 4.—Glanders bacillus; culture on potato, forty eight hours old, at 37.6° C.; fuc camera lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 5.—Tetanus bacillus; old culture on bouillon, showing battledore forms an spores; camera lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 6.—Bacillus of bubonic plague; agar culture, twenty four hours old; fuchsin; c lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

PLATE I.

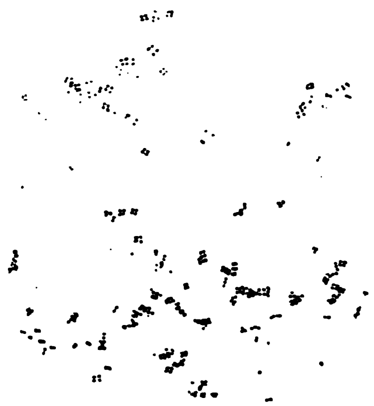


FIG. 1.

FIG. 2.

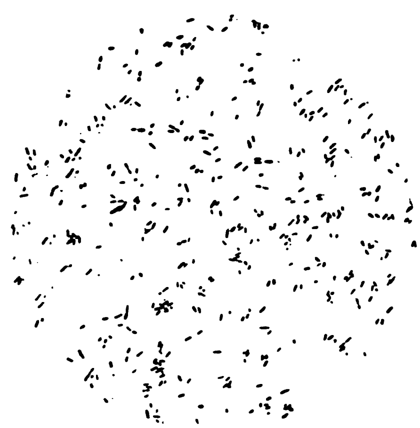


FIG. 3.

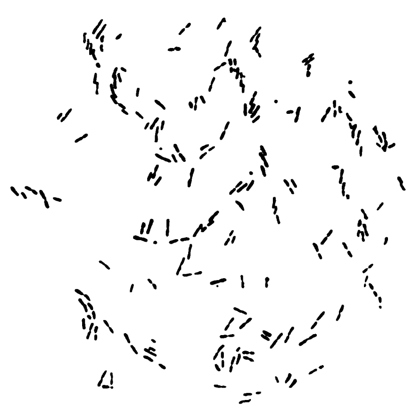


FIG. 4.

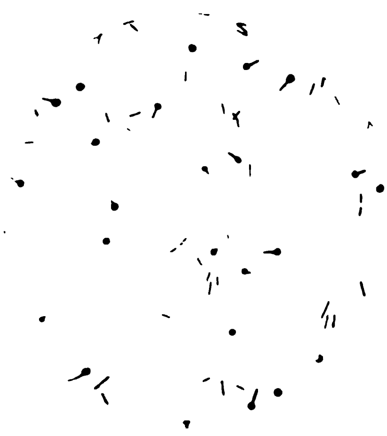


FIG. 5.

FIG. 6.

ceding, whose characteristics are precisely the same, with the exception that its colonies are white, and not colored.

The Staphylococcus epidermidis albus of Welch is probably but a variety of the preceding, occurring in the deeper layers of the skin.

A third micrococcus of pus, much less common than either of these two, is the **Staphylococcus pyogenes citreus,** differing from the others in that its colonies are of a lemon yellow, and the fact that its pathogenic properties are very slight.

The **Staphylococcus cereus albus** and the **Staphylococcus cereus flavus** are of practically no importance. They are found occasionally in suppurative processes. They do not liquefy gelatin; the one produces a white waxy growth upon ordinary media, whilst the other produces a yellow waxy growth. They have not been shown to have any special pathogenic properties.

The **Streptococcus pyogenes** (Plate 1, Fig. 2) is a coccus of a somewhat larger average size than the staphylococcus, being about 1 μ in diameter, occurring in chains which may be made up of a large or a small number of the cells. Sometimes there is the appearance of a chain of diplococci, because the division of many individual members of the chain may be going on at the same time. In young cultures the micrococci are uniform in size; but as they grow older a marked difference appears, some of the individuals being twice the normal diameter and more. This streptococcus is non-motile. On cultivation in gelatin a very thin line appears along the needle-track, which is seen to be made up of a row of minute round colonies, whitish in color, rarely reaching the size of a pin's head. There is no growth on the surface of the gelatin, and no liquefaction or color-production. In gelatin plates the colonies also appear as minute whitish globular points, flat and translucent upon the surface. On the surface of agar the growth takes place along the needle-track as minute rounded colonies, showing a marked tendency to remain separate. The characteristics upon blood-serum are the same as upon agar; on potato there is generally no visible growth; in bouillon there is apparent a very fine cloudiness, which later settles to the bottom of the tube. It coagulates milk, and is said occasionally to produce gas in sugar media and to turn litmus red. It grows best at the temperature of the body, and with a fair degree of rapidity. It does not produce spores, does not liquefy gelatin, and produces no pigment. It stains with any of the anilin colors and by Gram's method. Inoculated into the ear of a rabbit, it produces a localized erysipelatous process; but usually subcutaneous injections in rabbits and guinea-pigs are without result.

It must be remembered that one of two things must be true: either there are many kinds of streptococci which our present means of study do not enable us to differentiate, or this streptococcus takes on many variations of virulence under the influence of varying surroundings.

Varieties of Streptococci.—It may be stated that formerly the Streptococcus pyogenes and the Streptococcus erysipelatis were regarded as two distinct species, and various points of difference between them were given. Further study, and especially the results obtained by modifying the virulence, have shown that these distinctions cannot be maintained, and now nearly all authorities are agreed that the two organisms are one and the same, erysipelas being produced when the Streptococcus pyogenes of a certain standard of virulence gains entrance to the lymphatics of the skin. Petruschky in 1896 showed conclusively that a streptococcus cultivated from pus may cause erysipelas in the human subject.

There is occasionally found, in the study of surgical lesions, a bacterium that produces a striking greenish-blue fluorescence in the nutrient media on which it grows. This is the *Bacillus pyocyaneus*, which is of interest not because it produces any pathological changes, but by reason of the studies that have been made upon the pigment which it produces, and its apparently augmenting effect when inoculated at the same time with certain other micro-organisms. It is one of a number, and the characteristics of the group are best studied in the large text-books.

The **Micrococcus tetragenus** is also an organism which very rarely occurs in surgical lesions, characterized especially by the fact that it divides in two planes at right angles to one another, so that it is frequently found in the tissues after inoculation in groups of four, sometimes surrounded by a capsule. The bacilli stain easily with all the ordinary stains, as well as by Gram's method. This micrococcus is about 1 μ in diameter. It grows readily in gelatin plates, as round yellowish-white colonies, which appear granular or slightly nodulated under a low power. The surface colonies show the yellowish-white color more markedly. The needle-culture in nutrient gelatin gives a fairly thick whitish line along the track of the needle, with a round, thick, yellowish-white disk on the surface. The organism grows abundantly on the surface of agar and of potato, in a moist layer of a yellowish-white color. It grows rapidly at the temperature of the room, does not produce spores, and does not liquefy gelatin. It is especially pathogenic to white mice, a subcutaneous injection

producing a general septicemia, the organisms being found in large numbers in the blood and tissues, especially the spleen. This micrococcus is supposed to be active in the production of the suppurative part of the destructive process in tuberculosis of the lung.

Can suppuration occur apart from bacteria? This question was taken up after it had been shown that bacteria were the chief causes of suppuration, and efforts were made to determine whether an actual suppuration could be determined by simple chemical substances, such as croton oil, nitrate of silver, mercury, and so on. The general conclusion reached seems to be that suppuration does not usually follow the introduction of these irritant substances; but occasionally with some of them, and in certain animals, a suppuration may occur, the pus from which does not show bacteria. This suppuration never produces secondary abscess of itself, nor upon inoculation of the pus, and it is even doubted whether the pus thus produced actually corresponds histologically and chemically with the results of natural suppuration; in any case, as far as the practical side is concerned, it is unquestionable that by far the greater number of cases of suppuration met with clinically are produced by living bacteria.

The **Bacillus coli communis** (Plate 1, Fig. 3) is found in many inflammatory and suppurative conditions in connection with the alimentary tract; also in other parts of the body, in inflammation of the urinary passages, cystitis, etc. It is a bacillus from 2 to 3 μ long and about 0.5 μ broad, with rounded ends. It is actively motile, and grows in gelatin plates as small brownish-white colonies, not liquefying the gelatin. In nutrient gelatin the growth is well marked along the needle-track, as a whitish line, spreading out upon the surface of the gelatin, not much elevated from the surface of the media; on agar it grows distinctly out from the needle-track, as a whitish-brown layer, moist, dirty in appearance; the same appearances characterize the growth on blood-serum; on potato, in forty-eight hours, there is a distinctly brown pellicle with a dull surface.

The growth clouds bouillon, produces gas in glucose media, turns litmus media red, and has a marked indol reaction in peptone solutions. It grows rapidly—best at the temperature of the body—does not produce spores, does not liquefy gelatin, produces gas (Plate 2, Fig. 2), and stains with any of the anilin colors, but not by Gram's method. Intravenous injection of small amounts in guinea-pigs will produce death, but much larger amounts are required to produce the same results in rabbits or guinea-pigs after intra-abdominal injection.

Muir and Ritchie give the following table of differences between the Bacillus typhosus and the Bacillus coli communis:

B. TYPHOSUS.	B. COLI COMMUNIS.
Flagella more numerous, longer and more wavy.	Flagella fewer and shorter.
In artificial media the growth is generally slow and not vigorous.	Growth faster and more vigorous.
Growth on fresh acid potatoes a nearly transparent film.	Growth on potatoes a brown pellicle.
Very slight acid-production in ordinary media, followed sometimes by the production of alkali.	Well-marked acid production.
Fermentation of lactose very slight, if any.	Fermentation pronounced.
Milk not coagulated.	Milk coagulated.
In gelatin "shake" cultures no gas-formation.	Abundant gas-formation. Rounded colonies.
No production of indol in ordinary bouillon.	Well-marked indol production. (In some varieties none. Klein.)
Widal's reaction. Bacilli become clumped together and motionless in the serum of a typhoid patient. (A similar reaction is given by the blood-serum of an animal immunized against the typhoid bacillus.)	Bacilli remain actively motile.

Of the bacteria already mentioned, the staphylococci are most commonly found in localized abscesses or pustules, carbuncles, boils,

PLATE 2.

1. 2. 3.

FIG. 1.—Staphylococcus pyogenes aureus; pure culture on blood-serum, four days old, at 37.6° C.; natural size.

FIG. 2.—Bacillus coli communis; pure culture on glucose-gelatin after forty-eight hours at 22° C., showing gas-production; natural size.

FIG. 3.—Bacillus tuberculosis; pure culture on glycerin-agar, three weeks old; natural size.

in acute suppurative periostitis, in ulcerated endocarditis, and in certain pyemic conditions. The streptococci are usually found in spreading inflammations, with or without suppuration, in diffuse phlegmonous and erysipelatous conditions, in suppurations in certain membranes, and in joints. The Bacillus coli communis is found in many inflammatory and suppurative conditions in connection with the alimentary tract and elsewhere. The Micrococcus tetragenus is found especially in suppurations in the region of the mouth or neck, as well as in various lesions of the respiratory tract. The Bacillus pyocyaneus is rarely found alone in pus.

The **gonococcus** is a constant accompaniment of that specific form of suppuration known as gonorrhea. Its special characteristic is that it is a micrococcus occurring most commonly in pairs, with the adjacent edges flattened or even slightly concave. Another of its marked characteristics is that it most commonly occurs in the leukocytes, which is different from what is the case in ordinary suppuration. It stains easily and well with any of the ordinary dyes, but does not stain by Gram's method.

Neisser's stain gives very beautiful results (Plate 3, Fig. 1). Cover-glasses in warm concentrated alcoholic eosin, two to three minutes. Transfer directly, after soaking off excess with filter-paper, to concentrated alcoholic methylene-blue, one-half to three-quarters of a minute. Wash in water, dry, and mount. (These times of staining have been found to be better than those originally given.)

The cultivation of the gonococcus is difficult. It does not grow upon the ordinary media. The best are solidified blood-serum and Wertheim's medium, consisting of 1 part of fluid serum and 2 parts of agar at a temperature of 40° C., which is then allowed to solidify by cooling. Growth occurs best at the temperature of the body, and does not go on below 25° C. The cultures are to be obtained by passing a small quantity of pus over the surface of one of the selected media, and then placing it in an incubator. The colonies make their appearance at the end of twenty-four hours as small translucent bodies, irregularly rounded, and reach their maximum size on the fourth or fifth day. The later cultures grow more luxuriantly than do the earlier ones, but the transference to fresh media must be made every two or three days. Aside from the occurrence of the gonococcus in fresh pus, its relation to joint-affections and other sequelæ is a matter of considerable importance. There is no question that in a certain number of cases of gonorrheal arthritis and in inflammations of the sheaths of tendons the gonococcus has been found microscopically, and pure cultures have been made; and also that in a large number of such cases no bacteria have been identified.

Certain peculiarities of the fluid in the joints in which the gonococcus has been found have been mentioned, such as a whitish-yellow tint, turbid appearance, shreds of fibrin-like material, sometimes almost purulent in its appearance; it has also been occasionally shown that the gonococci are more numerous on the surface of the membrane lining the synovial cavity than in the fluid.

For diagnostic purposes the appearance of the gonococci in pairs, their characteristic arrangement within the cell-protoplasm in fresh pus, staining easily with the ordinary colors and not staining by Gram, furnish the group of microscopic appearances. For the determination by cultivation Wertheim's medium, or blood-agar, should be used, or Wright's urine-serum-agar, as described below.

Urine-serum-agar (Mallory and Wright, p. 132) is useful, as demonstrated by Wright, for the cultivation of the gonococcus. To a quantity of melted agar-agar at 40° C. is added a mixture of 1 part urine and 2 parts beef blood-serum equal to 1/3 to 1/2 the volume of the agar-agar. The mixture of urine and serum is freed from bacteria by passing through a Chamberland filter. The mixture is allowed to solidify in test-tubes, and must be tested for contamination in the incubator.

Soft Chancre.—For some years little attention was paid to this lesion, because there was a widespread opinion that it was a filth-disease; but later observations, notably those of Ducrey and Unna, have shown the constant presence of a bacillus in this form of ulceration, and no other, although it has not been possible to cultivate it upon artificial media. It is a

small oval rod, about 1.5 μ in length and 0.5 μ in breadth, and occurs in the discharge from the surface, or, in sections, more deeply situated than other bacteria, in bunches and in chains that may be stained in cover-glass preparations. Great care must be taken not to decolorize too strongly, for the bacillus itself is easily decolorized.

Syphilis.—The bacillus of Lustgarten, described about fourteen years ago, is the only one that has ever been ascribed to this disease with any appearance of probability; and while it resembles in certain respects both the bacillus of tuberculosis and the smegma bacillus, it may be differentiated from either of them by a special method.

Lustgarten's staining of the tissues to demonstrate the bacilli was as follows: Place the sections for from twenty-four to forty-eight hours in anilin-water gentian violet; then wash in alcohol, and place for ten seconds in a 1½ per cent. solution of potassium permanganate; decolorize with sulphurous acid (25 per cent. solution) to remove the brown precipitate as well as to decolorize the tissues; wash in water; dehydrate and mount.

Like the bacillus of soft chancre, this syphilis bacillus has not been successfully cultivated.

Hueppe's method of differentiating between the syphilis, smegma, leprosy, and tuberculosis bacilli is: 1. Treat the preparation, stained with carbol-fuchsin, with sulphuric acid; the syphilis bacillus becomes decolorized almost instantaneously. 2. If not at once decolorized, treat with alcohol; this will remove the color from the smegma bacillus. 3. If still not decolorized, it is either the bacillus of tuberculosis or that of leprosy. (Adapted from Abbott's *Bacteriology*.)

Diplococcus Pneumoniæ (Fränkel's pneumococcus; Microbe of *Sputum septicemia; Micrococcus Pasteuri; Diplococcus lanceolatus*).—Under these headings may be placed a description of the diplococcus that, while not usually producing primary surgical results, may often occur associated with the pyogenic cocci. It is of grave importance in medicine. It occurs not infrequently in the saliva of healthy persons, with great abundance in the expectoration of certain forms of pneumonia, and has been studied associated with the septic cocci.

The best method for securing a pure culture is by subcutaneous inoculation of material containing it (Plate 3, Fig. 2) in rabbits or guinea-pigs; in which case the animals die in from twenty-four to forty-eight hours, and the blood and tissues are found to be filled with this micro-organism. It is an oval coccus, occurring usually in pairs, and may be surrounded by a capsule. The colonies are not apparent upon ordinary gelatin plates or in gelatin tubes, for the reason that the bacterium does not grow below 22° C., so that cultures are best seen after development upon agar at the temperature of the blood. In this case the colonies appear as minute, almost transparent drops, looking almost like small drops of water. They grow best upon blood-serum, as an almost transparent line along the needle-track, with isolated colonies at the edges, later becoming more or less confluent. The colonies on agar plates are almost invisible, but may be seen by means of a low-power lens, and appear to have a compact, finely granulated center, with almost translucent edges. There is a slight cloudiness produced in bouillon, which later settles to the bottom of the test-tube. There is no visible growth upon potato. It is very difficult to keep the cultures alive, and to do so they must be renewed every three or four days, and even then are fairly certain to die out in the course of two or three months. It is impossible to retain the virulence of the micro-organism under cultivation. This must be done by the passage through animals. Its growth is slow except at the temperature of the body. It does not produce spores, does not liquefy gelatin, does not produce gas, is facultatively anaërobic, stains with the ordinary dyes and by Gram's method, and produces septicemia upon subcutaneous inoculation.

Tuberculosis.—The bacillus of tuberculosis occurs in all lesions of the disease. It is a small rod, on the average from 2.5 to 3.5 μ in length and 0.3 μ in breadth. It occurs singly or in pairs, arranged either end to end or like the arms of the letter V. It is non-motile. The unstained portions of the rod have been by some supposed to be spores, but this is not generally accepted. It does not grow upon ordinary gelatin or upon ordinary nutrient agar. It does, however, develop upon both of these media if from 6 to 8 per cent. of glycerin have been added to them (Plate 2, Fig. 3). Its best growth, however, is found upon blood-serum at the temperature of the body. On this medium its colonies present a characteristic appearance. They are seen first as small brownish-yellow dots, and never before the eighth or ninth day. They increase in size, coalesce, and form a heavy, wrinkled, dirty-brown or cream-colored layer extending outward three or four lines on each side of the needle-track, and in undisturbed cultures grow upon the surface of the water of condensation, leaving the fluid below perfectly clear. Once seen, these colonies are almost unmistakable for anything else. The growth upon potato, which is sometimes seen, but not always, presents similar characteristics. The bacillus is of slow growth, develops only at the temperature of the body, does not liquefy gelatin, probably does not produce spores, produces no gas or odor, stains with difficulty with the ordinary anilin colors, decolorizes with equal difficulty, and produces tuberculosis upon inoculation in all susceptible animals. The difficulties in cultivating the bacillus of tuberculosis would present an almost insuper-

FIG. 1.—Gonococcus in pus, stained by Neisser's method; camera lucida, oc. immersion $\frac{1}{12}$ (Zeiss).

FIG. 2.—Croupous pneumonia sputum, showing Fränkel's diplococcus and cap Ziehl's carbol-fuchsin; camera lucida, oc. 4, oil immersion $\frac{1}{12}$ (Zeiss).

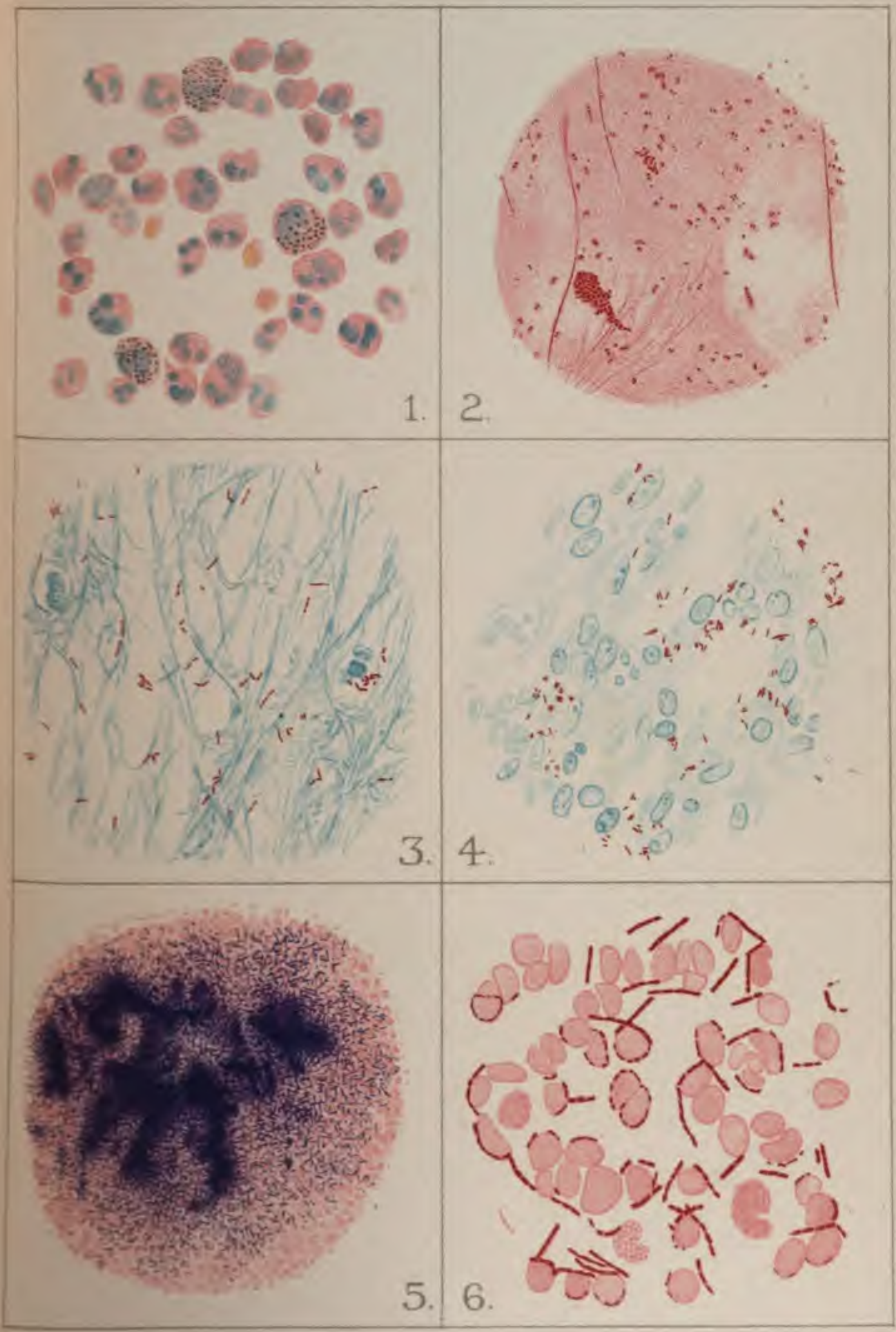
FIG. 3.—Bacillus tuberculosis in sputum; Koch-Ehrlich stain; camera lucida, oc immersion $\frac{1}{12}$ (Zeiss).

FIG. 4.—Bacillus tuberculosis in human gland; Koch-Ehrlich stain; camera luci 4, oil immersion $\frac{1}{12}$ (Zeiss).

FIG. 5.—Bacillus actinomyces in human gland; stained by Gram's method; c lucida, oc. 4, obj. 5 (Zeiss).

FIG. 6.—Anthrax bacilli in the heart's blood of a mouse; fuchsin; camera lucida oil immersion $\frac{1}{12}$ (Zeiss).

PLATE 3.



able obstacle to the diagnosis of tuberculous processes by this method. Fortunately, however, Ehrlich showed that this bacillus has a special staining reaction by which it may be differentiated from any others with which it is likely to be confounded. Taking advantage of the resistance of this bacterium to the decolorizing action of the mineral acids, Koch and Ehrlich worked out a differential stain, than which no better method has ever been suggested for the detection of small numbers of the bacilli in suspected material. For cover-glasses this method is as follows:

1. Cover-glasses prepared in the usual way are stained over night—better for twenty-four hours—in anilin-water fuchsin (or gentian violet). 2. Transfer at the end of that time to nitric acid (1 : 4) for a few seconds. 3. Place in 60 per cent. alcohol for one minute to complete decolorizing. 4. Wash in water. 5. Stain in watery methylene blue (or vesuvin, if gentian violet was the first stain used) for one to two minutes; wash thoroughly; dry carefully; mount in oil of cedar or Canada balsam (Plate 3, Fig. 3).

Sections are stained in precisely the same way, with the exception that in place of the nitric acid, 1 part to 4, a little stronger bath of nitric acid is used, 1 part to 3, because, the sections being thicker than the film on the cover-glass, a somewhat stronger decolorizing agent is necessary. Of course, after the washing following the use of the methylene blue, the sections are to be dehydrated, cleared in oil of cedar, and mounted in Canada balsam (Plate 3, Fig. 4).

The efficiency of this stain lies in the fact that the nitric acid appears to exert some direct coagulant (?) action upon the capsule of the bacillus itself. This action is practically instantaneous, and results in placing the capsule in such a condition that it resists the further decolorizing action of the nitric acid, so that the bacillus remains stained. This is not true with other bacilli; all other bacteria are completely decolorized, except the bacillus of leprosy and the smegma bacillus; and if the source of the material allows any possibility of confusion with these two, the method of differentiation already given will serve to put an end to any doubt.

The method as given by Koch suggests the use of gentian violet as the first stain (with fuchsin as the second choice) and vesuvin as the contrast stain (with methylene blue as the second choice), the result of which would be, of course, a blue-stained body upon a brown ground; whilst the method preferred here, gives red-stained rods upon a blue ground. This is the result that has been found by far the most useful, for it is much more easy for the eye of the average student to detect a minute red body upon a blue ground than it is to find a minute blue body upon a brown ground. Much objection is constantly raised to this method of staining because of the time that must elapse before the material is ready for the microscope, and innumerable short ready methods have been suggested, not one of which is as reliable as this, but many of which are much more used.

The most common of these is the so-called Ziehl's method. In this method, as in the others, advantage is taken of the resistance of the bacillus of tuberculosis to decolorizing agents. As in the first method given the anilin oil is used as a mordant to intensify the action of the first stain, so in this method the aid of a still stronger mordant is sought and found in carbolic acid. The first procedure in the Ziehl-Nielsen method, which is applicable only to cover-glasses, is as follows: Cover-glasses prepared after the usual method are stained in carbol fuchsin for thirty minutes (this time may be shortened to ten minutes by warming the staining fluid); decolorize in sulphuric acid (1 part to 4) for a few seconds; wash in water; a contrast stain is obtained by watery methylene blue for two or three minutes; the cover-glasses are then thoroughly washed in water, carefully dried, and mounted. In this method, as there is a stronger mordant used in the carbolic acid, so there is a stronger decolorant used in sulphuric acid. Experience has demonstrated that while this stain may be useful for showing the presence of large numbers of bacilli, it cannot be relied upon when there are but few. Of this method, as of all the short methods yet presented, it may be said that if one finds rods stained red on a blue ground, the presence of the bacilli may be acknowledged; yet if such rods are not found, the absence of the bacilli cannot with safety be asserted.

Gabbet's method of staining is one frequently used, combining the decolorizing and the second stain. 1. Stain cover-glasses with carbol-fuchsin, hot, for one minute. 2. Wash in water. 3. One half minute in Gabbet's methylene blue (Methylene blue 2, sulphuric acid 25, water 75). 4. Wash thoroughly, dry, and mount.

In examining suspected material for purposes of diagnosis in tuberculosis, cover-glass preparations are to be made in quite large numbers, and thoroughly studied after being stained by one or more of the methods suggested; but inoculation experiments are sometimes successful when the microscopic examination fails, so that recourse should be had to these inoculation experiments if the matter of diagnosis is one of importance and the microscopic examination has failed to demonstrate the bacilli. Inoculation experiments are more commonly necessary in the diagnosis of surgical tuberculosis than in other forms of the disease. The bacillus being more often present in the granulations and lining membranes of abscess-cavities, it is to be looked for especially in these tissues rather than in the contained fluid.

Glanders.—Glanders occurs not infrequently in human beings by direct infection from diseased animals. Occasionally it is a matter of importance to be able to make a differential diagnosis between this disease, as manifested in the human subject, and certain other conditions. There is a specific bacillus connected with the disease, discovered by Löffler and Schutz, the announcement being made in 1882. The bacillus which is found in the tissues affected has been subjected to observation under artificial conditions, and the disease has been reproduced upon inoculation. The bacillus is a small rod, from 1–2 μ in length, either straight or slightly curved, and with round ends (Plate 1, Fig. 4). Portions of the protoplasm not infrequently refuse to take the stains, and somewhat resemble spores. The glanders bacillus is non-motile. Satisfactory study of the colonies in gelatin cannot be obtained, for the reason that the glanders bacillus does not develop, excepting very slightly, below 25° C. On agar the culture appears along the needle-track as a grayish-white, slightly transparent layer, moist and slimy, which later becomes of a brownish color. On blood-serum the growth is somewhat similar but more translucent, separate colonies occurring in the form of round, almost clear drops. Blood-serum is by far the best medium for its development. In bouillon there is at first a uniform cloudiness, which later settles to the bottom, forming a thick, flocculent deposit. On potato the glanders bacillus grows very well at blood temperature, forming a marked, elevated, translucent yellowish growth, almost like clear honey; later the growth becomes darker and more opaque, until at about the end of a week it takes on a reddish-brown or chocolate color, while the potato at the margin of the colony often shows a greenish-yellow stain. This growth is characteristic of the glanders bacillus, taken in connection with the microscopic appearance. The development of the bacillus is rapid at blood temperature. It probably does not produce spores, for, although it is not killed at once by drying, it loses its vitality in about two weeks in a dry state. The cultures retain their vitality for from two to four months if removed from the incubator after growth has occurred, but they die quickly—in from three to four weeks—when kept constantly at the body-temperature. They have but slight powers of resistance to heat and antiseptics; all of which tends to show that they do not produce spores. The bacillus does not liquefy gelatin, nor does it produce gas; it produces the yellowish honey-like color. It stains with the ordinary watery solutions but faintly, and decolorizes very readily indeed, so that a fairly strong stain should be used in the first place, and very mild measures of decolorization should afterward be employed. The alkaline methylene blue of Löffler for five minutes; then decolorize for a few seconds in a mixture of water 10 c.c., 10 drops of a strong solution of sulphurous acid, and 1 drop of a 5 per cent. solution of oxalic acid (as recommended by Löffler). Muir and Ritchie obtained the best results with carbol-Thionin-blue,[1] dehydrating by the anilin-oil method. In using, dilute 1 part with 3 parts of water, and filter. Stain sections for five minutes or upward. Wash very thoroughly in water, to prevent later deposit of crystals. Decolorize with very weak acetic acid (a few drops to a glassful of water). Wash thoroughly in water. Dehydrate, and clear with anilin oil, then with anilin oil and xylol equal parts, then with xylol. This bacillus does not stain by Gram's method.

The diagnosis of glanders may be readily made by taking advantage of the peculiar affinity that the glanders bacillus has for the testicular tissue of the guinea-pig. If a small portion of the suspected material be injected subcutaneously over the abdomen of a male guinea-pig, the testicles will become much enlarged in from twenty-four hours to three days if the glanders bacilli be present. Microscopic examination of tissue-scrapings will show the presence of the bacilli in large numbers.

Leprosy.—Leprosy, so far as surgical bacteriology is concerned, need be spoken of only to say that in the lesions there always occur, especially in the tubercular form, large numbers of bacilli that microscopically and in staining reaction resemble very closely the bacillus of tuberculosis. They are present for the most part within the protoplasm of the round-cell infiltration, and are frequently arranged in bundles lying side by side; occasionally one or two are found on the surface epithelium, although for the most part they are confined to the leukocytes and the connective-tissue elements. They have not been satisfactorily cultivated outside of the body. For microscopic observation cover-glass preparations may be made from any ulcerations found, or from scrapings from a portion of excised tissue. They may be stained by Gram's method, or by carbol-fuchsin, using, for decolorizing, a weaker solution of sulphuric acid than in the case of the bacillus of tuberculosis, for the reason that the bacillus of leprosy is decolorized more easily than is the bacillus of tuberculosis. A contrast-stain may be obtained with the watery solution of methylene blue.

Actinomycosis.—The fungus producing this disease is not a true bacterium, but it is of great interest, because certain cases of surgical disturbance are produced by it; and by observation of the actinomycosis fungus a differential diagnosis from tuberculosis or other

[1] *Carbol-Thionin-Blue.*—Stock solution of 1 gm. Thionin-blue in 100 c.c. carbolic-acid solution, 1 : 40.

processes may not infrequently be made. In the tissues the fungus forms little round masses, the largest being of the size of a small pin's head, lying free in the pus, if the breaking down of the tissues has gone so far as suppuration, or embedded in the granular tissue. They may be of various colors, usually described as yellow, but this is not the most common appearance. They are more frequently white, greenish, or almost black, whilst they may be also transparent or jelly-like. Under the microscope there occur: 1. Filaments, on the average, 0.5 μ in diameter, and often of considerable length (Plate 3, Fig. 5). In the center of the colony these filaments are frequently interlaced, and at the edges often spread out in a more or less symmetrically radiating manner. The name "ray fungus" has been given because of this appearance. 2. Cocci or conidia, which are spherical bodies formed from the filaments, probably by transverse subdivision. 3. Club-shaped bodies found at the periphery of the colonies, and really the filaments with swollen sheaths.

These organisms do not stain by Gram's method, but take the contrast-stain. They do not always occur in affected human tissues, but may be found very frequently, practically always, in the ox, and in the tissues from this animal they retain the gentian violet in Gram's stain.

The origin of this parasite is probably on grain, especially on barley. The obtaining of pure cultures is extremely difficult, and while growth occurs at the ordinary temperature of the room, it is very slow. Portions of the tissue should be broken up on the surface of glycerin-agar and placed at the temperature of the body. If there are no other bacteria present, in three or four days the colonies will appear in the form of small transparent drops, gradually enlarging, forming rounded elevations of a reddish-yellow color. The colonies are dull, adhere to the surface of the agar, and sometimes have a wrinkled surface and an appearance as if they had been covered with a brownish-yellow powder. The parasite grows well also in the anaërobic condition on agar. Unopened eggs, either fresh or boiled, have also been used, the inoculation being made through a small hole drilled in the shell, which is afterward closed. On gelatin whole spherical colonies appear, and there occurs very slow liquefaction, the liquefied portion being brownish and thick, with the colonies at the bottom as little balls. The growth upon potato is very similar to that upon agar.

Anthrax (*Woolsorters' disease; Malignant pustule; Splenic fever*).—This process, with its bacillus, is of great interest because it is one of the first in which the bacteria were connected with disease; by reason of the fact that the action of germicides is tested upon anthrax spores; and because it was one of the first affections in which immunity by the use of attenuated cultures was sought to be obtained.

The bacilli occur in the blood and tissues of man or animals attacked by anthrax (Plate 3, Fig. 6). They are from 6 to 8 μ long and about 1.2 μ broad, with square or slightly concave ends. They sometimes occur in long chains, frequently in pairs arranged end to end. They stain well with all the basic anilin colors, and by Gram's method, although a cautious application of the decolorizing fluid is necessary in order to avoid removing the gentian violet from many of the bacilli. On gelatin plates the colonies develop, in from twenty-four to thirty-six hours, as very wavy bodies, radiating from the center outward like locks of hair. In a day or two a liquefaction begins which slowly extends through to the bottom of the gelatin. In gelatin tubes an appearance is seen similar to that of the colonies in gelatin plates, the growth appearing along the needle-track as a whitish line sending out radiating lines and presenting the appearance of an inverted fir-tree, whitish, and accompanied by liquefaction slowly progressing downward from the upper portion of the gelatin. In agar plates the colonies are apparent twelve hours after incubation at a temperature of 37° C., under a low power, presenting this very marked wavy appearance. Under a high power the wavy appearance apparently radiates out, and terminates not in a point, but in a turn upon itself; so that it is probable that the entire colony is a thread twisted on itself. On the surface of agar there is a moist, profuse growth, slightly elevated, and whitish in color, showing the wreathed appearance that is seen in plate-cultures. The colonies on blood-serum are the same as on agar. In bouillon there appears a shreddy growth that later becomes more abundant, settling as a flocculent mass to the bottom of the fluid. On potato there is a thick, moist, whitish layer, without any special characteristics. The bacillus grows rapidly, producing spores, does not produce gas, liquefies gelatin slowly, does not produce pigment, is stained readily with any of the anilin colors, and usually by Gram's method, and is pathogenic to all susceptible animals.

For diagnostic purposes cover-glass preparations may be made from the fluid in the vesicles, or from scrapings of the incised pustule, and may be stained with watery solutions of any of the anilin colors, and by Gram's method. The bacilli are not usually found in the blood. Muir and Ritchie give a very wise caution that the parts should be handled carefully and gently in attempts at diagnosis, otherwise the diffusion of the bacilli into surrounding tissues may be forced, and the condition greatly aggravated. Plate-cultures should also be made, as well as inoculations, if positive results are not obtained by the microscope alone.

Tetanus.—The etiology of tetanus was slow in development, from a bacteriological

point of view, for the reason, demonstrated after a long series of investigations, that t bacillus of tetanus does not usually grow excepting under anaërobic conditions.

This bacillus was first described by Nicolaier in 1885, but Kitasato was the first to s ceed in cultivating it separate from other bacteria. The bacillus itself is from 4 to 5 μ lc and 0.5 μ broad, with somewhat rounded ends (Plate 1, Fig. 5), and without any spec characteristics except when it is in the spore-producing stage. In this case the spore occ at one end of the rod, is round, and has a diameter three or four times the thickness of rod. In specimens stained with a watery solution of gentian violet or methylene blue spores are unstained excepting at the edges, so that the appearance of a small ring is p duced. The rods occur singly or in threads. The bacilli are motile, and when stained demonstrate the cilia, they are seen to occur either singly, or at both ends, or all about rod.

Inasmuch as the bacillus does not usually grow excepting under anaërobic conditic ordinary plate-cultures are not commonly attempted for obtaining the pure cultures from discharge in which the spore-bearing tetanus bacilli have been seen. Muir and Rit suggest the following method:

Inoculations with the suspected material are made in half a dozen deep tubes of gluc agar, previously melted and kept at a temperature of 100° C. After inoculation these tu are again placed in boiling wâter, and kept for varying times—from half a minute, to c two, three, four, five, or six minutes; they are then plunged in cold water until cold, and afterward placed in an incubator at 37° C., in the hope that in one or the other of tubes all the organisms present will have been killed except the tetanus spores, which develop in pure culture. The isolation of the tetanus bacilli is in many cases a diffi matter, and various expedients must be tried. If this attempt at securing pure cultures successful, further cultures can be made in deep upright tubes of glucose-gelatin or a In agar the growth is not characteristic, the colonies appearing as small nodules along needle-track, with very slight formation of gas; in glucose-gelatin the growth occurs inch or two below the surface, and consists of fine, straight threads, rather longer in lower than in the upper part of the tube, radiating out from the needle-track, together slight liquefaction and slight gas-formation. Growth also occurs in blood-serum and cose-bouillon under anaërobic conditions. By far the best development is at a tempera of 37° C., and only in the absence of oxygen, the bacillus being anaërobic. Spores produced at the end of twenty-four hours in cultures grown at 37° C., much later at lc temperatures. The bacillus produces gas in sugar media, may be stained easily by an the anilin dyes and by Gram's method, and is pathogenic to the lower animals, reprodu the disease upon inoculation in small quantities. There is very little to be found m scopically, except localized punctate hemorrhages in the spinal canal; not much ch occurs in the other organs of the body.

Attempts have been made to determine the nature of the tetanus toxin—for with disease, as with diphtheria, the main symptoms are the result of the action of toxin prod during the growth of the bacillus—and very extensive experiments have been conducte the direction of securing an antitetanus serum.

The experiments in the production of immunity against tetanus in animals have successful; but the use of the serum of immunized horses in cases of human tetanus has been equally so, probably because the symptoms of tetanus do not appear sufficiently ma until the progress of the disease has passed beyond the stage at which curative treatme likely to be successful.

For the bacteriologic examination of a suspected case, there should be, first, the m scopic examination of the secretion from the wound, which may easily fail unless the d stick forms are found; cultures in deep tubes of glucose-agar or glucose-gelatin shoul made, kept at the temperature of the body for twenty-four hours, and then examined, v the spore-bearing bacilli may be detected; finally, inoculation experiments should be upon mice or guinea-pigs.

Occasionally it seems to be true, as demonstrated by Theobald Smith, that the tet bacillus will grow in mixed cultures not under the ordinary anaërobic conditions. In cases a possible explanation is that the oxygen in the nutrient medium is used up by other bacteria. Advantage has been taken of this peculiarity by R. M. Pearce, of the Bc City Hospital, who has succeeded in isolating the tetanus bacillus from a mixed cultu which it had developed.

Malignant Edema.—This disease occurs in human beings as a spreading inflan tory edema, accompanied by emphysema, and later followed by gangrene of the skin adjacent parts. The disease is produced by the bacillus of malignant edema, first desc by Pasteur as the "vibrion septique." Like the bacillus of tetanus, this bacillus is pr not uncommonly in garden-soil, manure, and various putrefying fluids. It is rather a bacillus, occurring in rods from 3 to 10 μ long, not infrequently growing out into long ments, but on solid media generally occurring as short rods with somewhat rounded e It is motile, with flagella placed on the sides. It forms spores, which are present us

at about the center of the rod. As this bacillus develops only under anaërobic conditions, it may be differentiated by this fact alone from the anthrax bacillus, which it somewhat resembles under the microscope.

In gelatin plates, under anaërobic conditions, the colonies appear as small whitish points, which under a low power show radiating appearances soon masked by a zone of liquefaction. In deep tubes of glucose-gelatin the growth appears as a whitish line, giving off minute short processes, never reaching within an inch of the top of the medium, with the occurrence of liquefaction and the settling of the colonies to the bottom. In deep tubes of glucose-agar at a temperature of 37° C. the growth is very rapid, as a broad white line along the line of puncture, with lateral projections here and there, and a very profuse production of gas. The cultures have a peculiar heavy odor that is quite characteristic. The growth is rapid; it produces spores that are well seen within forty-eight hours at 37° C.; it produces gas, liquefies gelatin, and stains easily with any of the anilin colors, but not by Gram's method; upon subcutaneous inoculation in any susceptible animal it produces the characteristic symptoms of widespread edema, gas-production, and gangrene.

For purposes of diagnosis, the microscope is not particularly useful, for, microscopically the bacillus, unless in the stage of spore-production, does not possess characteristics sufficient to identify it. Cultures may be made in glucose-gelatin as roll-cultures, and kept under anaërobic conditions. If the bacilli contain spores, the fluid may be kept at a temperature of 80° C. for ten minutes, and then a deep glucose-agar tube should be inoculated and kept at the temperature of the body. An inoculation experiment with the suspected material may also be tried in guinea-pigs.

Bubonic Plague.—Whilst bubonic plague does not occur in America, there is more or less constant danger of its transmission from Hong Kong or India to the Pacific Coast; and the fear of an epidemic was aroused recently, so that a description of the bacillus described independently by Kitasato and by Yersin may not be out of place.

The bacillus is found in the glands affected by this disease as small oval rods with rounded ends. Many of the bacilli stain at the ends only, leaving an unstained portion in the center. They usually occur singly, but not infrequently are found in pairs; and in cultures, especially in fluid media, they have a tendency to grow into chains (Plate 1, Fig. 6). They are non-motile, appearing in gelatin plates as small spherical, whitish colonies, without liquefaction. In gelatin tubes the colonies grow along the needle-track as isolated globular, whitish bodies, with a thin, semi-transparent layer on the surface. On agar the growth is along the line of the needle-track, whitish, smooth, shiny, somewhat transparent in appearance, and made up of isolated colonies growing together. The same appearance is seen upon blood-serum. In bouillon the growth collects especially along the foot and sides of the tube. The bacillus grows rapidly at the temperature of the body, or as low as 18° C. It does not produce spores; it does not produce gas; it does not liquefy gelatin; it stains easily with any of the anilin colors, but does not stain by Gram's method.

All the smaller animals usually used for experiment are readily susceptible to the inoculation. They become affected with an inflammatory swelling of the lymphatic glands, and especially by a profuse diarrhea. It has been noted that during an epidemic of bubonic plague an especially high rate of mortality has occurred among rats and mice in the infected district, and it is thought that such a mortality is not infrequently the beginning of an epidemic among human beings.

Yersin appears to have been successful in his attempts to secure an anti-plague serum, but the reports are not yet sufficiently detailed to permit a proper appreciation of their importance.

Rhinoscleroma.—Rhinoscleroma is rare in America and in England, but is not uncommon in some parts of the continent of Europe. It is characterized by chronic nodular thickenings of the skin or the mucous membrane of the nose, pharynx, larynx, or trachea. In the tissues of these nodules bacilli have been found—short oval rods surrounded by a distinct capsule.

In its microscopic and cultural appearances the bacillus of rhinoscleroma resembles very closely that of Friedländer; and while slight differences have been made out, it is undoubtedly a member of the same group. These differences, as summarized by Baumgarten, are that this bacillus always has a capsule, in cultures as well as in the tissues; that it is more decidedly rod-shaped than the bacillus of Friedländer; and that it stains by Gram's method, whilst Friedländer's bacillus does not. The bacillus of rhinoscleroma is a short bacillus with rounded ends, occurring singly and in pairs, and surrounded by a distinct capsule. It is non-motile. On gelatin plates the colonies appear as yellowish-white granular bodies in two or three days. In gelatin tubes the growth appears along the needle-track as a whitish granular line, and as an almost hemispherical elevation on the surface, giving the appearance, in profile, of a round-headed nail driven into the gelatin. Upon the surface of agar the growth is profuse along and on both sides of the needle-track, as a dirty-white moist layer; on potato a profuse cream-white growth occurs along the surface. The best growth is at a temperature of 37° C. The growth is fairly rapid. The bacillus is non-spore-bear-

ing, non-liquefying, and aërobic. It stains easily with any of the anilin colors, and Gram's method, and is pathogenic for mice and guinea-pigs, but less so for rabbits.

The **Bacillus aerogenes capsulatus,** as described by Welch and Flexner,[1] is interesting bacterium that may be found at autopsies, but which has not yet been shown possess pathogenic properties in man. It is a rod from 3 to 6 μ in length and 0.5 to 1 breadth, with rounded or square ends, occurring singly, in pairs, and occasionally in ch or threads. Being strictly anaërobic, cultures must be made under these conditions. C nies are gray or brownish white, with a central darker spot by transmitted light, increa to 2 to 3 mm. in size. Deep colonies may be oval or spherical, with feathery projecti The bacillus is non-pathogenic, but the tissues of animals (rabbits) killed immediately the intravenous injection of a suspension of bouillon, and kept for a few hours at a temp ture of 30° to 50° C., contain a large amount of gas and many bacilli.

DEVELOPMENT OF SERUM-THERAPEUTICS.

The advance in our knowledge of bacteria has led to great incre of activity in attempts to prevent the appearance of the sympt of an infectious disease after exposure to its virus, or the arrest cure of these symptoms after they have made their appearance. S attempts have, of course, been made from the time when medi began, but have met with the smallest amount of success so far as use of drugs, as this term is commonly employed, is concerned. first efforts with a knowledge of the bacteria and their action as a b were those in which the attempt was made to secure the attenua of the virus of the disease, and the use of this modified virus aga an attack of the disease itself. The idea underlying this is the sul tution of a disease of a milder type for that of the full strength, attack of the milder form being supposed to protect the system aga the more virulent. Such attempts have been carried on with at l partial success in such diseases as anthrax and rabies. They repre the direction in which the earliest efforts of Pasteur and his follo were made. These investigators have not thus far, however, see to define any general principle upon which further work may be ba nor do their results seem to serve as a foundation for reasoning, cept in the individual disease that the experiments cover.

Tuberculin is the result of efforts along a different line, illustrates the attempt to establish a different principle. It sists essentially of the nutrient material in which the bacteria grown, freed of the bacteria by filtration, but containing all the c pounds that have resulted from their growth. The use of this mat (tuberculin) is an example of the second method, by means of w it has been sought to secure curative effects in infectious disease; is, by the application of the products of bacterial growth, as obta in the test-tube, to the destruction of the organisms that prod them, or at least to the arrest of the development of these organi

The third and apparently the most successful method for com ing the infectious diseases, from the therapeutic point of view, is employment of certain properties that may be naturally presen artificially produced in the blood-serum of various animals.

It is a long time since the theory that immunity might be du some chemical element in the blood was suggested—this subst being something that would prevent the growth of the invading [illegible] has been an exceedi

[1] [illegible]

difficult matter to sift the conflicting evidence offered. The first experimental researches were negative (Grawitz and Gamaleia); but in 1884, Grohmann showed that fresh serum exerted an attenuating influence upon the bacilli of symptomatic anthrax; Fodor found that fresh blood destroyed them; while Nuttall established the fact that organic fluids (serum, aqueous humor, pericardial fluid), really possessed the power of destroying bacteria, and that this germicidal action was taken away by raising these fluids to a temperature of above 50° C. Buchner found that this power rested solely in the serum, and that the breaking up or mixing in of the blood-corpuscles masked or diminished its activity. Following Buchner, the important work was that of Ogata and Iasuhara, and Behring and Kitasato in pointing out the great influence of the fluid portions of the animal tissues in the production of immunity. From the work of these authors it appears that immunity is due to the action of albuminoid substances, called by Hankin "defensive proteids," which have the power of (1) destroying pathogenic bacteria, (2) of attenuating them, or (3) of neutralizing the effects of or destroying their toxic products.

First as to the "germicidal proteids." Certain animals have in their blood and the other fluids of their body substances endowed with a very considerable germicidal action, an example that has been much studied being the blood of the white rat. These animals are refractory to inoculation with anthrax, and the reason for this immunity to a disease so virulent has been found (Behring) to exist in the fact that the animal's blood-serum destroys the bacterium. By comparative tests it was shown that 2½ c.cm. of rat's serum would have the same germicidal action as would the same quantity of corrosive sublimate in the strength of 1 : 1000, or of carbolic acid 1 : 50. To appreciate this fact it is necessary to consider another quality of these chemicals —their toxic action upon the animals. It thus appears that the sublimate and carbolic-acid solutions will *kill* the animal in a dose one-fifth to one-seventh of that necessary to secure their germicidal action, and cannot, therefore, be thought of for internal antisepsis. On the other hand, the germicidal proteids are present in quantity sufficient for complete activity in the serum of a perfectly healthy white rat. These proteids are, therefore, the least toxic of all germicides known. Many points are still to be made out—as, for instance, such an apparent contradiction as that the germicidal power does not in all cases correspond to the natural immunity of the animal that furnishes the serum; but at least, as the experimental knowledge of the subject has increased, working hypotheses have been suggested for most of these contradictions.

The second class of these proteids is made up of the "attenuating" varieties, the existence of which was first suggested by the fact that the bacteria of symptomatic anthrax were attenuated in virulence when injected into animals refractory to the disease, whilst their vitality was not interfered with. The experiments of Ogata and Iasuhara first showed that the attenuating property lay in the serum of the animals experimented upon. The existence of these attenuating proteids has apparently been demonstrated by other observers in anthrax and other diseases.

The progress of research has, however, shown that there is a *third* class of proteids, the *antitoxic;* and their discovery is the most important of all, not only because the results obtained with them are so important, but because it almost appears that the germicidal and attenuating proteids are to be included among the antitoxic. The two former are supposed to act upon the bacteria themselves; the last, upon their products. The first announcement of results in this direction was made by Behring and Kitasato in 1890. They had found that the blood of rabbits protected against tetanus had the power of destroying the toxic alkaloid of tetanus (tetanin) during the lifetime of the animal attacked, and that it was not only possible to protect an animal against inoculation of the tetanus bacilli, but also to *cure* it after the appearance of the symptoms of the disease. The application of these facts to human tetanus has not been as successful as was at first hoped for, probably because it is not usually possible to apply the remedy sufficiently early in the disease.

Almost in the same week with the announcements of Behring and Kitasato with reference to tetanus came those of Fränkel and Brieger upon diphtheria, which have been followed by such striking results in the treatment of this disease in man.

Very similar results have been obtained in animals in the case of some of the suppurative bacteria, the streptococci, and in anthrax and swine-erysipelas. The important fact has also been demonstrated that each disease is a problem by itself, and that the minuter details of technic must be worked out for each one.

CHAPTER II.

HYPEREMIA; INFLAMMATION; LOCAL INFECTION AND ITS TERMINATIONS.

HYPEREMIA.

THE old term "congestion" was used to denote a condition closely allied to inflammation, but as pathology and histology became more accurate the condition known as hyperemia was sharply defined from inflammation. The term was used to denote a functional instead of an organic disturbance. Inflammation was then divided into simple and septic inflammations, the former being caused by trauma in some form, and the latter by bacteria. Since the recognition of bacteria as the source of a constantly enlarging number of inflammatory processes, some writers have inclined to the view that all true inflammations are septic. Many of those processes, known still as inflammations by most writers, but which could not be placed under this category, have been assigned by some surgeons (Park and Senn) back again to the domain of "congestion."

If, however, we adhere closely to pathological and physiological conditions, we find that there is an essential difference between the hyperemias and even the simpler forms of inflammation. In hyperemia we have a more or less transitory change of function, which leaves the tissues essentially as they were before. In inflammation, on the other hand, there is a distinct organic change brought about by an influence which has produced more profound disturbance.

Hyperemia signifies an increased amount of blood in a part, and is in contrast with ischemia, which means a decreased flow of blood to a part. It is of two kinds, active and passive. In active hyperemia there is an increased flow of arterial blood. In passive hyperemia there is a slowing of the blood-current—a stagnation—and the blood is venous in color.

Active Hyperemia.—In this form of hyperemia there is an increased rapidity of the flow of blood through both the arteries and veins, and the color of the part is a bright red; there is even an arterial color in the smaller veins of the part, and at times they seem to pulsate. Under the microscope it can be seen that the capillaries are filled with arterial blood, and they also appear to be dilated (Fig. 11). Ordinarily there is no edema, as the vessels hold the fluid and no exudation takes place. It is rare that there is any extravasation of blood as the result of active hyperemia. There is an increased warmth in the part affected, as more warm blood from the interior of the body flows through it.

The vasomotor nerves concerned in these functional changes a the vasoconstrictors, the vasodilators, and the perivascular ganglia

Hyperemia of paralysis is that form of active hyperemia produc by the paralysis of the vasoconstrictors. This condition may be pı duced experimentally by division of the splanchnics, which produce dilatation of the mesenteric and renal arteries. This congestion m be so extensive as to withdraw blood from the greater part of the bo

FIG. 11.—Normal circulation in vein, artery, and capillary.

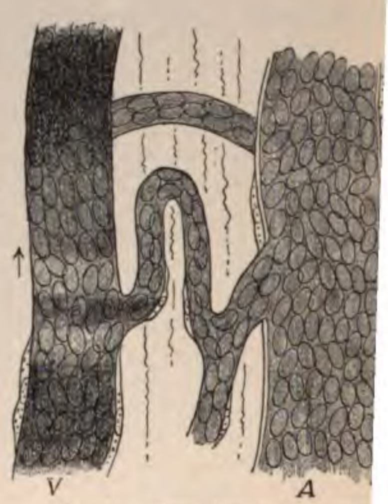


FIG. 12.—Circulation in hyperemia.

producing a condition similar to that known in the so-called Goltz periment, which consists in tapping the abdomen of the frog with but frequent blows. This causes a temporary cessation of respira heart-pulsation, and muscular action, from which condition, how the animal speedily recovers.

Gröningen reports the case of a laborer, lying on his back after a full meal, wh playfully hit upon the stomach with a plank; in fifteen minutes he was dead, and autopsy no structural lesion could be found in any part of the body. A more fa example of hyperemia of paralysis is gunshot injury of the cervical sympathetic, in flushing of that side of the face occurs, and also dilatation of the pupil of the sam with redness of the conjunctiva, secretion of tears, and hyperidrosis. Such a conditi been observed, after fracture of the clavicle, from pressure on the cervical sympathetic

Hyperemia of irritation is caused by irritation of the vasod nerves. It is shorter and quicker in its action, and is accomp often by other active nervous symptoms, such as pain. The flu accompanying facial neuralgia and herpes zoster is supposed to b to this variety. Reflex hyperemias belong to this class.

Hyperemia caused by paralysis of the perivascular ganglia is form produced by purely local causes, such as pressure. This i form seen after removal of the Esmarch bandage, or tapping the men for ascites, or suddenly emptying an overdistended bladder.

Active hyperemia, of whatever form, is a passing condition, and when the congestion has subsided there is no appreciative change in the affected part. It may, however, predispose to inflammatory changes, as the resisting power of a tissue thus affected is diminished, and a soil may be made favorable to bacterial infection.

FIG. 13.—Passive hyperemia.

Passive hyperemia is due to partial or complete obstruction of the flow of blood through the veins. It is purely mechanical in character. There is cyanosis of the part affected, and its temperature is subnormal. If the small veins and capillaries, when in this condition, are observed under the microscope, they are found to be distended with blood-corpuscles which appear to be more or less fused together. The flow of blood ceases at certain points, and extravasation of red blood-corpuscles occurs (Fig. 13). There is at the same time an escape from the vessels of a certain amount of fluid, giving rise to edema.

A familiar example is seen in the lower extremities in varicose veins. Here all the stages of the process can be seen. At first there is only edema. Later there is pigmentation of the skin, due to the destruction of the extravasated red blood-corpuscles. The impairment of the tissues thus brought about may ultimately lead to ulceration. Hypostatic congestion is another form of passive hyperemia, and when it occurs in the lungs, as it often does in the aged when confined to bed, it may pave the way for pneumonia. It is due to the enfeebled circulation in many forms of disease that pressure upon certain points of the body readily causes passive congestion and stasis—thus giving rise to bed-sores.

INFLAMMATION.

Inflammation may be divided into two principal varieties—simple and infective. To the former variety belong those produced by trauma or injury (such as a fracture) and those due to chemical action (such as that produced by drugs, as salivation, or that produced by ivy-poisoning, or the action of escharotics). The infective inflammations are those produced by bacteria or the chemical substances evolved by them.

In *simple inflammation* we have a disturbance in the nutrition of a part, brought about usually by trauma, which has been best expressed by the word "damage." It may be defined as a lesion in the mechanism of nutrition, owing to which its efficiency is impaired, but which, if not so severe as to cause death, produces conditions favorable for the protection and repair of the part.

As will be seen presently, there is, in addition to the congestion of

hyperemia, a leakage of the vessels which gives rise to exudation an other processes which produce an organic change in the part affecte

It was formerly supposed that these changes were part of the pro ess of repair, and that a smart reaction was needed, after an injury, bring about an active reparative process to ensure the healing of wound. The changes produced by inflammations are, on the contrar those expressive of destruction rather than repair. In the type inflammation of which we are speaking there are no progressi changes such as are seen in the infective form, but simply those resu ing from injury. They are fortunately of such a nature as to favor t process of repair, which in due time makes itself manifest.

The causes of simple inflammation are not only trauma, but those which are not bacterial. In addition to the chemical acti above referred to, the question has been raised as to the rôle played the nerves in inflammation.

The influence of the nerves has long been recognized as an ag active in the nutrition of a part. The theory of the trophic action the nerves was based upon the experiments on the vagus and geminus.

After division of the ophthalmic branch of the fifth pair a necrosis of the cornea occ and the so-called vagus-pneumonia follows division of that nerve. These inflamma are now classed with the infective inflammations, as it is known that, the protective ir vation having been withdrawn, the tissues are exposed to bacterial action. Still, clinic we meet with many types of inflammation so intimately associated with reflex action th is difficult to assume that all are due solely to bacteria. Many of the cases of urethral which are supposed to be typical examples of reflex inflammation are now well known due to infection; but a certain number are difficult to account for in any other way tha an action of the nerves. The nerves may at least be placed in a prominent position ar the predisposing causes of inflammation. Age also has a marked influence upon the pro Disturbances of nutrition in growing children lead readily to inflammations which ar likely to occur in adults, such as affections of the mucous membranes and the bones. old age the power of resistance to invading organisms is less marked, and sepsis is readily produced. Morbid conditions of the blood (such as gout, scurvy, and diab subject the patient to inflammation of the joints and of the mucous membrane and the Climate is also a potent factor.

Inflammation was primarily divided into several varieties, such as pathic, traumatic, sthenic, and asthenic. These terms are now lar discarded. Such terms as "hemorrhagic," "parenchymatous," "interstitial" have more interest for the pathologist than for the geon.

Pathology.—The seat of inflammation is the connective substa principally—that is, those parts concerned in the nutrition of the b If we take the connective tissue, we find these changes observe their simplest form. The first change noticed is in the blood-ve If a frog be paralyzed by curare and a loop of intestine be d through an incision made in the abdominal wall, the action of the sels can readily be studied during the inflammatory process excite the exposure of the peritoneum. There is at first a marked a hyperemia. The vessels are distended with arterial blood, and nu ous capillaries are observed which before were invisible. The incr rapidity of the blood-flow lasts, however, but for a short time, a followed by a slowing of the current, which soon becomes slower normal. A marked change now occurs in the interior of the

veins and capillaries. Along the walls of the veins there may now be noticed an accumulation of white corpuscles, which increase in number to such an extent that the entire vessel-wall appears to be lined with them. Presently the phenomena of diapedesis of the white corpuscles (Fig. 14) takes place, and leukocytes are found in large numbers in the surrounding connective tissue. At the same time there is considerable leakage of fluid or blood-plasma from the vessels into the meshes of the surrounding tissue. The fluid coagulates, and in the fibrils of fibrin which are thus formed are found the white corpuscles. This is known as "exudation." Fibrin is formed by the union of the fibrinogen of the blood-plasma with the paraglobulin and fibrin-ferment found in the white blood-corpuscles. These leukocytes, in virtue of their ameboid movements, wander freely in the tissues, and the exudation then spreads over a considerable microscopic area (Fig. 15). Many of them break up and liberate the substances necessary for the process of coagulation.

FIG. 14.—The blood-vessels in inflammation: Diapedesis of white corpuscles.

It will be seen that the process here described is essentially different from hyperemia. The vessels have been damaged and leak, and the

FIG. 15.—Ameboid movements of a leukocyte.

changes in their power to conduct the blood through them are marked. The rapidity with which the blood flows varies greatly in different parts of an inflamed area. On the periphery the velocity of the current is greatly increased, as is readily shown by an incision, through which

the small vessels force their blood with great vigor. The nearer we approach the central point of an actively congested area, the slower is the current; and at times when the lesion of the part has been greatly increased, there may be stasis or stoppage of the flow. There is great variability in the rapidity of the flow of blood, according to the local conditions.

The changes seen in the blood in simple inflammations are not important, the increase in the number of white corpuscles, or leukocytosis, being more characteristic of infective, or more strictly speaking, suppurative inflammations.[1]

The changes seen in the tissues are those produced by the great increase in the cells of the part. The cells of connective tissue are known as the fixed and the wandering cells. The fixed cells are stellate or fusiform, and lie hidden between the fibers which constitute the principal portion of the intercellular substance. In addition to these are the small round cells, containing one or more nuclei and a granular protoplasm, in all respects resembling the white corpuscles of the blood. These are the so-called wandering cells. When the tissues are irritated or inflamed, these cells are found in large numbers. When the theory of cell-emigration was adopted there was an inclination to reject the old theory of cell-proliferation. The numerous cells found in a part were supposed to be emigrated leukocytes, and the subsequent changes found in the part, by which new tissue replaced the old, were supposed to be effected largely through the agency of the wandering cells.

After an inflamed tissue has reached this stage, we find that the cells of the part predominate over all other elements. The intercellular substance becomes less apparent, the fibers disappear, and a granular material takes their place. The tissue is thus considerably modified in its physical properties; it becomes rigid and less pliable, and at the same time loses its tough and flexible characteristics. A "cake" forms, which indicates the outline of the inflamed area. The tissue thus formed is known as "granulation-tissue," for it is of tissue like this that the granulations seen upon the open surface of wounds are composed. When the inflammatory process begins to subside, these cells gradually disappear: some wander into the adjacent lymphatics and are taken back into the circulation again; others are broken down and absorbed. New intercellular substance makes its appearance, and, with the gradual process of repair, new tissue is found to replace any loss of substance which may have occurred during the inflammatory process. If these different stages follow one another without suppuration having taken place, the inflammation is said to have terminated by resolution. The same series of processes is observed in wounds healing by first intention, and it is in this way that the edges of a wound become adherent and finally unite.

There has been much dispute about the functions of the leukocytes. When Cohnheim first brought them to the attention of the profession, he assumed that they performed the duty in the process of repair hitherto ascribed to the cells of the part. The fixed cells were thought by him to take no part in the process of repair. It has, however, been shown that the fixed cells undergo active changes, by means of which cell-division and multiplication

1 See section on Pathology of the Blood.

occur. In the nucleus changes known as karyokinesis occur, by means of which the so-called indirect cell-division takes place (Fig. 16). Many of the new cells seen in the inflamed part are the offspring of such changes. It is these cells which play a prominent part in the process of repair. It is now thought that many of the leukocytes which are seen in such large numbers serve as pabulum for the proliferating fixed cells, and that others play

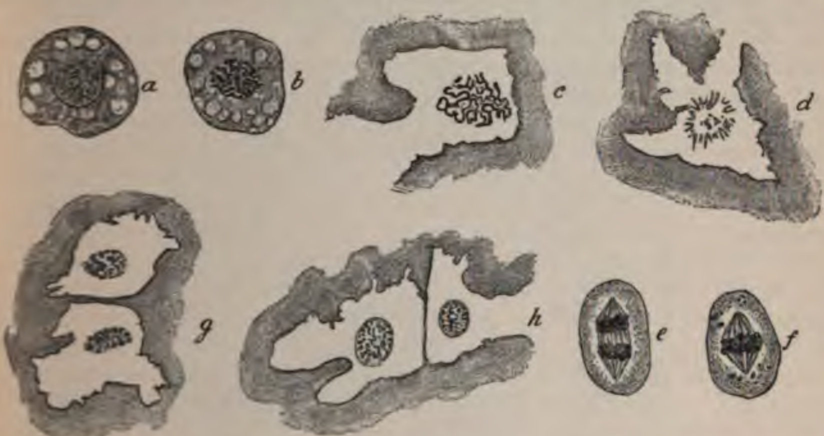


FIG. 16.—Changes occurring in the nucleus of a cell during process of division by karyokinesis.

the rôle of scavengers, owing to the power possessed by them of appropriating particles of foreign bodies or bacteria and transporting them to distant points. The usefulness of the leukocytes in consuming and receiving portions of broken-down tissue can easily be understood, as it is in this way that absorption is facilitated, by means of which disposal is made of dead substances, blood-clots, exudations, and bacteria.

Cells which are specially endowed with this property are known as phagocytes (Fig. 17),

FIG. 17.—Phagocyte from exudate of cerebrospinal meningitis, containing leukocytes and cell-detritus.

and are supposed to exercise a protective influence in the body. This theory was advanced by Metschnikoff, who showed that in those diseases in which the tissues were succumbing to the bacteria, no micro-organisms were found in these cells; but that in case the system was able to throw off the bacteria, remains of destroyed micro-organisms were found in the phagocytes.

Metschnikoff endeavored in this way to explain the immunity which certain tissues have

for certain forms of bacteria. Although the antibacterial action or antitoxic properti the blood-serum are now better understood than when this theory was first advanced theory of phagocytosis still has many adherents, and it is probable that these cells p prominent part in the pathological process in protecting the surrounding tissue from invasion of disease. These are the principal changes observed in an inflamed area there is no suppuration, and when repair follows after the subsidence of the more prom symptoms of inflammation which have resulted from injury.

FIG. 18.—Giant cell containing glanders bacilli in the subcutaneous tissue.

Symptoms of Inflammation.—There are five cardinal symp of inflammation—pain, heat, redness, swelling, and impaired fur (dolor, calor, rubor, tumor, and functio læsa).

These symptoms vary greatly in different forms of inflammati in inflammation of different tissues. In the simple inflammati such, for instance, as that following a fracture of the leg—the red is not so marked as in an acute septic inflammation. In inflamm of the internal organs there is no increase of heat over that surrounding healthy structures. In bone there is at first no sw when it is inflamed.

The **rubor** or **redness** is due to the increased determination of to the part. In acute inflammations, particularly in the septic the color is bright red or scarlet. An incision with the knife bri quick gush of bright arterial blood. The color is lighter at t riphery of an inflammatory swelling, and deepens toward the where the current is more impeded in its action. In very severe of inflammation the congestion is often excessive, and the s vessels are overdistended with red blood-corpuscles. Under the cumstances there may be an escape of the red corpuscles as the leukocytes through the walls of the vessels, and in such case are collected together in little groups, forming punctiform ecchy This condition is seen in the "hemorrhagic" forms of inflamr An abundant exudation may diminish the brightness of the col give it a yellowish tinge. The color of an inflamed mucous mer

is much deeper than that of the skin, owing to the close proximity of the blood-vessels to the surface. The color is absent in bloodless parts, as the cornea.

The **tumor** or **swelling** is due to the exudation poured out from the vessels into the inflamed part. This collects in the meshes of the tissue or is poured from the surface of the membranes. In easily distensible parts near an acute inflammation the amount of fluid exuded is quite large. This is known as collateral edema. The prepuce and the eyelids are often greatly swollen even where the amount of adjacent inflammation is slight. In the thigh we may have exudation and swelling on a large scale following fracture of the bone or an acute osteomyelitis.

The **dolor** or **pain** is due to the pressure on the terminal branches of the nerves, and consequently it differs greatly according to the distensibility of the part or to the amount of exudation or to the nerve-supply. In unyielding tissue, such as bone, the pain is at first most severe. In all tissues the pain is more severe at the beginning of an inflammation, while the tissues are in process of being stretched.

Pain is of different kinds. Throbbing pain is due to the extra pressure exerted by the arterioles during systole in somewhat rigid and sensitive parts like the fingers.

Boring pains are felt in chronic inflammation of bone. A lancinating pain suggests the breaking down or tearing apart of tissues during the approach of pus to the surface, and is suggestive of the "breaking" of an abscess.

Soreness is a form of less severe pain; it is due to an acute inflammation in a yielding but superficially sensitive structure. The boil is the proverbial type of this form of pain.

Itching is always said to be a good sign, and correctly so, for it is the residual morbid sensation which remains when pain disappears. It is due to the presence of the products of exudation in the vicinity of the terminal nerve-branches.

Some portions of the body are far more sensitive than others. Fissure of the anus is an example of severe pain caused by a slight disturbance in an extremely sensitive locality. Pain in certain organs is often referred to distant points. Thus the pain of a diseased hip may be felt in the knee. Pain at the neck of the bladder is felt at the meatus of the urethra.

Calor or **heat** is due to the increased flow of blood through the inflamed part. The amount of heat generated in the diseased area is extremely small, and does not account for the increased warmth.

The fifth and last symptom of inflammation is **functio læsa.** A muscle that is the seat of an inflammatory exudation is rigid, and cannot contract like a healthy muscle. Mucous membranes may secrete a much greater quantity of mucus when inflamed, or they may be unnaturally dry. The special senses are all impaired in their functions when the corresponding organs are inflamed.

Inflammation may terminate either in resolution, in death of the part, or in suppuration.

Termination by resolution occurs when the various symptoms gradually subside and the part returns to its normal condition. This is seen in simple inflammations following injury when the process of repair is

well under way. A simple inflammation does not tend to spread, its symptoms, after full development during the first two or three d begin gradually to disappear.

If the congestion of the blood-vessels has been so severe as cause a stoppage in the flow of blood, or stasis, the affected area die and a "slough" is formed; or if the area is extensive the cha is called "gangrene." The dead part is separated from the live ti by the formation of a line of demarcation caused by a suppuratior the adjacent living tissues. If the dead or necrosed area is sma may, if on the surface, form a dry scab, under which repair of the substance will take place without suppuration. If it is in the int of the body, it is usually called an "infarction," and may shrivel be replaced by cicatricial tissue, also without suppuration.

Suppuration may occur only in connection with bacterial infec and will be considered under that head.

Treatment.—The treatment of simple inflammation is dire chiefly to relieve the symptoms and favor resolution—that is, to vent such injury to the tissues as may lead to death or suppura Rest is one of the most important agents in minimizing the am of damage to the parts from injury. This tends to keep dowr exaggeration of the symptoms, such as the swelling and the These may be relieved also by the application of heat in the for a poultice, or of cold. An ice-bag placed upon a knee which recently been sprained will relieve the pain and frequently preve undue exudation of synovial fluid into the joint.

The soothing action of cold usually makes it a welcome applic If the swelling is great, and the circulation is sluggish, the color d and the temperature of the part low, cold is not indicated, as the ity of the part may thus be imperilled.

Cold can be employed by means of either a rubber ice-bag ice-coil, by means of which a continuous stream of cold water exert its influence upon the part.

Heat acts differently according to the degree used. Warm tices favor an increase of hyperemia and consequent flushing part. The exudation may thus be increased until pus forms; flushing of the part with fresh blood-serum thus produced may duce conditions unfavorable to the growth of bacteria, or may away the products of exudation, and thus favor absorption. G heat constricts the blood-vessels; thus, a hot poultice freq applied, or the hot douche, will sometimes check an incipient i mation; chronic congestions are often greatly relieved in this

Venesection is now a discarded remedy, but was not without in certain critical conditions. Local bloodletting is still much u relieve the dangerous tension caused by some congestions, or to the resolution of obstinate chronic inflammations. Leeching excellent remedy for the relief of local pain, and has also a sti ing effect upon the absorbents. It is a most useful means of re congestion and promoting absorption in certain cases, and would less be employed oftener were nurses properly trained to the a tion of leeches. In some injuries, where vessels have been ru and internal hemorrhage has taken place, the safety of a limb

at stake when the swelling of inflammation supervenes upon that of the injury. The skin is tense and shining, the color is dusky, and the blood flows slowly back into its channels after being forced away by pressure. This condition is often accompanied by severe pain. Under these circumstances free incisions are indicated to relieve the passive hyperemia. The venous blood can now escape, and is replaced by fresh arterial blood which otherwise could not have entered the limb. The relief of pressure opens the collateral vessels, and the circulation is once more restored. Such incisions should be sufficiently long and deep to give free relief to tension. They should be carried down through the skin and superficial fascia, and through the muscular fascia if necessary. If done with thorough aseptic precautions, a simple fracture may be converted into a compound fracture temporarily, and, after the crisis is passed, the wound may be closed again in two or three days if desired. The superficial scarifications often employed are of little or no value. If it is desired to avoid a long incision, alternating short incisions may be substituted, or numerous deep punctures can be made with the point of the knife, and the flow of blood and serum may be promoted by antiseptic fomentations. Moist applications upon fresh open wounds thus made often pave the way for future suppurations. The large incision, with dry aseptic gauze dressing, is therefore the safer method.

Counterirritation is of much value in chronic forms of inflammation, and may be applied by the actual cautery, the blister, or by milder measures, such as tincture of iodin or mustard plasters. The actual cautery is still often used in chronic tuberculosis of joints or other chronic forms of joint-inflammation. It may be applied by the Paquelin cautery on several isolated points or in crossing lines. The application can be repeated a week or two later. Iodin is useful when a milder and more continuous irritation is desired. The part to which the application is made should receive two coats at first. The iodin may then be painted on daily for one or two days, after which it is well to wait a day or two for the irritation thus caused to subside before repeating the application. The fly-blister is a powerful absorbent. If such an effect be desired, a blister about one inch square may be applied, and two or three days later, after the blister thus produced has dried and the skin has exfoliated, a second blister may be applied upon the same spot. This usually produces a marked irritation of the skin, extending to the subcutaneous tissue. When the swelling thus produced is absorbed, the old infiltration, enlarged gland, or bursal effusion also frequently disappears. Dry and wet cups are out of fashion, but are undoubtedly valuable agents in the dispersion of chronic and deep-seated exudations which resist the ordinary remedies.

Compression is a valuable agent to keep down swelling in the early stages of inflammation and to produce the absorption of effusion in its later stages. It must be applied with care whenever there is any question as to the integrity of the circulation. In injuries of joints the effusion is often markedly restrained by equable pressure, and the period of convalescence is thus diminished. Pressure will cause old inflamed glands or other chronic and rebellious swellings to disappear.

To be applied efficiently to any portion of a limb, it should be used conjunction with a splint. Thus, in the case of housemaid's knee ham splint having been applied, a compressed sponge of appropri size can be bandaged firmly to the swollen bursa, after which moist should be applied to the sponge to increase the local pressure. T whole knee-joint may be firmly compressed in this way.

Rest is essential in the treatment of inflammation. For this p pose the patient should be confined to bed if the inflamed part cann be rested in any other way. In acute inflammations of the blad such a precaution is essential. The lower extremity should be vated, and, indeed, it may be said that elevation of the inflamed p wherever situated, is a valuable adjunct to the treatment. In disea of the prostate gland elevation of the hips often gives marked re to the symptoms.

Physiological rest of such organs as the bladder or the brain is most valuable in n cases. In some brain injuries absolute mental quietude is essential for many weeks the accident. In certain forms of chronic cystitis which do not yield to other treatmen opening into the bladder by cystotomy will give the needed rest, and is often followe prompt amelioration of the symptoms.

Massage.—After the inflammatory swelling has subsided the m cles are found to be smaller and less pliable, the tendons do not m easily in their sheaths, and the capsules of joints are matted toge and do not unfold readily. The limb is stiff and unservicea attempts to use it are followed by increase of pain, and frequently some of the other of the old symptoms from which it has suffered. is in this stage that massage is of value. Massage is deep rubbing, is a great advance over the superficial rubbing produced by linim By massage the deep-seated exudations are softened and the circ tion in the deep lymphatics is re-established, so that absorption goe again. The circulation of the blood also becomes more active, so the disabled parts receive proper nourishment. The term "rubbi includes kneading, pressure, and such manipulations as will transf rigid into limber structures. Passive motion is a valuable adjunc massage, as it stretches muscles and thus restores their function. also loosens the shrunken capsule, and enables the tendon to slid and fro again through its sheath. Unless the parts have been soft sufficiently by massage, passive motion may lacerate the imperf organized exudations and cause hemorrhage and inflammation, w will, of course, retard the process of convalescence. It should tl fore be used only after the acute symptoms of inflammation have sided and massage has paved the way for bending and stretching affected tissues. In the aged and feeble the disease of a limb or a may lead to permanent disability if the important aids to the treat of inflammation are neglected. In cases of injury awaiting tri actions of tort, this portion of the treatment is usually neglected one has an opportunity to see how long a limb may remain disabl proper measures are not taken to restore the function of the part.

Constitutional Treatment.—The old heroic methods of purg and emetics and resolvents have passed away, and the "antiphlogi treatment has been superseded by the antiseptic treatment, and now generally recognized that supporting measures are of more ir

ance than the old depleting system. Inflammation means damage, and the constitutional disturbance which precedes or accompanies it is usually in the nature of either shock or fever. Both of these conditions lower the vitality of the system and render it less capable of exerting its natural powers of recovery. Every opportunity should be given it to do this. Rest to the body is therefore important, as well as rest to the injured member. There should be no waste of tissue or strength allowed, as all is needed for repair.

The patient should be kept quiet during the period of pyrexia, as at this time the system is peculiarly susceptible to outward influences, and complications of various kinds may in this way be avoided. Suitable rest can best be obtained in bed if there is much fever, and under such conditions no patient should be allowed to be the judge of what suits his own peculiar temperament. Proper ventilation of the sick-chamber is essential, but neither the nurse nor the patient should be allowed to decide how this should best be accomplished.

Diet is of great importance, and should be as nourishing as is possible under existing conditions. The stomach should be supplied with nutritious and quite digestible food. Milk is the most valuable of all liquid forms of food, and can be readily digested at all periods of life, in spite of the popular prejudice that it is apt to "disagree." Care should be taken to have a good article, and if there is any doubt as to its quality, it should be sterilized. Mixed with lime-water or bicarbonate of potassium, milk is less liable to coagulate and to cause indigestion, and if given at first in this way and in small quantities, it can usually be well borne even by those who are unaccustomed to it as an article of diet. It is, however, contraindicated after operations upon the perineum or rectum, or in any case when it is important to avoid for several days a movement of the bowels, owing to the large amount of fecal residue which remains after it has been digested. A liquid diet without milk should be employed under these circumstances. Meat-broths should then be substituted, and in small quantities, some of the lighter forms of solid food may be given, such as eggs, or finely chopped meat, or beef- or chicken-jelly. Tea, cocoa, and coffee in small quantities relieve the monotony of this form of diet. Pure water should always be given, and the nurse should be reminded that this is an essential article on the diet-list. When given in small quantities and frequently, it favors heat-dissipation, helps to bring about lysis, and contributes greatly to the comfort of the patient. In a few days after a surgical operation a varied solid diet may be ordered in the majority of cases. When food cannot be retained by the stomach, nutrient enemata may be administered. Enemata of water or of normal salt-solution often give great relief to thirst. A few drops of laudanum may be added to an enema if there is any doubt about the patient being able to retain it.

Alcoholic stimulants are valuable during fever if the pulse shows signs of weakness. They are a safeguard against sepsis. The stomach should, however, be carefully watched during their administration. Many individuals who are wholly unaccustomed to the use of alcohol bear it well in the septic forms of fever. Then alcohol becomes a food, and one of the most valuable kind. During convalescence light wines

or beer will prove valuable aids in restoring strength, and are oft preferable to tonics.

Antipyretics have little permanent influence upon fever, and, owir to their debilitating effect upon the heart's action, are usually contr indicated in surgical cases. They may, however, be used to relie pain, particularly of a spasmodic character, and those forms of pain spasm which recur at certain regular intervals. They may then serviceable in breaking up an annoying complication of this nature.

Mercury was formerly used with great freedom in all inflammatory processes, as it supposed to exert a resolvent action upon fibrinous exudation. Its use has, with justi been very generally discarded at the present time.

Purgatives were also used freely under the antiphlogistic syste They are now indicated only as a preventive against the storing up the intestinal tract of materials likely to lead to auto-inoculation. Th exert a derivative action in threatening inflammation or congestions the meninges of the brain, as they relieve the tension of the circulati and remove all sources of reflex irritation from the intestinal canal.

In threatening peritonitis laxatives are indicated to restore the n mal peristaltic movements and to act upon the secreting powers of intestinal mucous membrane, and thus draw freely upon any fluids t may exist in the peritoneal cavity in the so-called "dead spaces."

Diaphoretics are but little used in this condition. Mild diaphoresis is of valu moderating fever and thus contributing to the comfort of the patient. The judicious of water as a drink, alone or combined with some mild drug, such as sweet spirits of n not only has this action, but is also sedative and diuretic.

Anodynes are most valuable in the treatment of inflammation, they not only relieve the most disagreeable symptom of inflammat —namely, pain—but give relief to the malaise of fever, and thus fa repose. Opium in the form of morphin is perhaps the most reliabl all anodynes. When a moderate action only is required, it can given by the mouth in doses of $\frac{1}{8}$ to $\frac{1}{6}$ of a grain. If there is question as to the ability of the stomach to retain it, or if it is turbed in its action by the drug, then the opiate may be given by rectum in a suppository. Subcutaneous injections of morphin are be used only when the pain is severe or a rapid action is essential. private practice the administration of a subcutaneous injection of m phin should be a rare occurrence with the surgeon. Occasion alarming symptoms of heart-failure are produced, perhaps by the jection of the fluid directly into a vein, or from idiosyncrasy. greater danger lies in the "habit," so readily acquired by patients. subcutaneous injection of morphin may be used in the first twenty- hours after an operation, and for one or two nights after a painful o ation, but it should never become a routine method of treatment.

Bromid of potassium will often relieve many attacks of so-ca "pain," which are really nothing more than discomfort and restlessr Neuralgic and spasmodic pain can be relieved, as shown above phenacetin. Sulfonal and trional are both useful as hypnotics, latter acting rather more rapidly than the former; but both are c uncertain in their action. Chloral in small doses, 5 to 7 grains, ca employed when other remedies fail; but care should be taken patients do not become too accustomed to the dose.

Tonics are indicated after fever has subsided. It is useless to give them during pyrexia, as they simply aid convalescence, but cannot prevail over an unfavorable condition. In case of fever they become an additional burden to the stomach. They are especially indicated in those cases where the appetite flags, and where it is desirable for various reasons not to recommend the use of alcohol. A young and healthy patient will convalesce from an injury or an operation under a generous diet without the aid of either.

On discharging a patient, careful directions should always be given as to the regulation of the mode of life and the precautions needed in the care of local conditions.

The average patient regards an operation as a panacea which enables him afterward to do as he pleases. Many an important case, conducted with great skill through the critical stages of healing, has finally come to grief through the neglect of some simple precautions by the patient himself. A convalescent is a man relieved, perhaps, from some grave disease, but for the time being with susceptibility to outward conditions to which previously he has been a stranger.

LOCAL INFECTION AND ITS TERMINATIONS.

That form of inflammation which is due to the action of bacteria is called infective inflammation. It differs markedly from simple inflammation in the severity of many of its symptoms. One of the most characteristic features of septic inflammation is its tendency to spread. Simple inflammation involves a certain area in a short space of time, according to the amount of injury inflicted, and then steadily subsides. Septic inflammation may spread indefinitely, and there is no certainty as to the extent of area which it may cover. The color of infective inflammation is also quite characteristic. The bright-red blush stands out in strong contrast to the surrounding tissues. All the symptoms are usually more pronounced, as the inflammation is essentially an acute one. There is, however, great variability in the symptoms, and in some of the most malignant forms of spreading sepsis there may be but little change in the color, the parts assuming the appearance of edema. The constitutional disturbance is always well pronounced, and goes hand in hand with the local conditions. Septic inflammation usually terminates in suppuration.

The organisms which are most commonly found in these conditions are known as the pyogenic organisms. They produce chemical changes in the tissue by the formation of a toxic substance or poison. The substances exert a peptonizing action upon the cells of the part, and cause a coagulation-necrosis or death of the tissues in the immediate neighborhood of a group of microbes, and bring about in the surrounding tissues a reaction which softens them and changes them into pus. In this way the affected area is separated from the rest of the body, and when the pus escapes the products of disease are discharged with it. Under less favorable conditions the reaction is less effective, the organisms continue to spread in the surrounding parts, and, although suppuration may take place, the walls of the suppurating cavity contain bacteria which are still in active growth and are invading new regions.

The most common forms of bacteria found in suppuration are the

pyogenic cocci, viz.: 1. The Staphylococcus pyogenes aureus, alb citreus, and epidermidis albus. 2. The Streptococcus pyogenes. (S Chapter I.) In addition to these, there is a variety of micro-organis which less frequently are the cause of suppuration.

The *Bacillus pyocyaneus* is an organism found in green and blue p It is not, strictly speaking, a pus-producing organism, and is genera associated with some other form of pyogenic coccus. The character tic greenish-blue color is usually found on the outer margins of t stained dressings. The *Bacillus pyogenes fœtidus* is found in the offe sive abscesses in the neighborhood of the rectum. The *Micrococ tetragenus* has been found in acute abscesses; the inflammation p duced by it is not usually severe, but is somewhat prolonged.

The *Bacillus coli communis*, or the colon bacillus, is found in norn discharges from the alimentary canal. It is found principally in t large intestine. It is a source of suppuration in parts liable to infect from these regions of the body.

This organism is found in active growth in suppurative and gangrenous appendic and has also been found in other forms of perforative peritonitis, and in suppurative p esses in the peritoneal cavity. Inasmuch as it is evacuated with the discharges, it ca obtained in cultures taken from the skin in the neighborhood of the anus, the vulva, occasionally the prepuce. It consequently may be introduced by instruments into the ge urinary tract, and become a source of suppuration along this route, producing cystitis pyelonephritis.

Other organisms, under favorable conditions, may lead to supp tion, such as the gonococcus, the pneumococcus, the typhoid baci and the organisms which produce the various forms of traum infective disease.

The *Streptococcus erysipelatis* is now regarded as identical with Streptococcus pyogenes. It does not usually produce suppuration may be the cause of minute cutaneous abscesses or the sprea forms of subcutaneous inflammation, known as phlegmonous sipelas.

The *Bacillus tuberculosis* does not cause the formation of pus cept possibly in exceptional cases. It is the organism which ca what is commonly known as cold abscess.

The *Amœba coli* is a protozoōn found frequently in the intes canal, principally in tropical climates. It is associated with ce forms of dysentery, and under these circumstances may pro abscess of the liver. The contents of such abscesses are a t brownish-red material, the products of broken-down liver-tissue r than true pus. When the latter is found, there is probably a n infection.

The question whether suppuration can be established withou intervention of bacteria is one about which there has been mucl pute. It is now pretty definitely settled that clinically we do not c suppuration in any other way than through the agency of micro-o isms. (See Chapter I.)

Immunity.—The pyogenic bacteria do not produce suppu in the body whenever introduced into it. It is only under c favorable conditions that this is accomplished.

Many bacteria are rapidly absorbed from the point of entra

that is, taken up into the circulation and swept into different parts of the body before they have an opportunity to grow locally. The rapidity with which they are eliminated from the system is often remarkable. They appear to be actually destroyed in the blood-serum itself, in virtue of a substance ("defensive proteid," "nuclein") which it contains, that exerts a germicidal action upon them. This substance is soluble only in an alkaline medium, and consequently it is necessary that the serum should be alkaline in order to possess this power. This substance is said to be derived largely from the leukocytes, which appear to have the power also of exerting a protective influence in virtue of their phagocytic action.

The German school relies chiefly upon the bactericidal powers of the blood-serum as a protective agent. The French school lays more stress upon the theory of phagocytosis. It is probable that local infection is resisted by the accumulation of leukocytes at the point of invasion, and that their protective powers are exerted partly in virtue of their phagocytic action and partly by a chemical substance given off by them (germicidal proteid). It seems also probable that protection against general infection is exerted by the blood-serum aided by the chemical substances given off by increased numbers of leukocytes.

The attraction of leukocytes to a point of infection appears to be due to a power of attracting cells, known as chemotaxis, a chemical attraction or irritation produced by the proteids of the bacteria.

After introduction into the body, bacteria are often found at distant points, as the lymphatics of the diaphragm or the capillaries of viscera. Here they are observed frequently in the leukocytes of the circulating blood or in the endothelium of the capillaries, the cells of which seem to possess active phagocytic properties. Those not destroyed may be eliminated by the kidneys, through the mucous membrane of the intestines, or even through the respiratory organs. Bacteria have also been found in the perspiration of individuals suffering from septicemia.

Among the **conditions favorable for infection** is the amount or **dose of the poison** received into the system. The experiments of various observers have shown that a very large number of bacteria may be injected without producing any result. Watson Cheyne found that it was necessary to inject a dose of 1,000,000,000 of the Staphylococcus pyogenes aureus into the muscles of a rabbit in order to produce a fatal result. As the human being is not very susceptible to the pyogenic organisms, considerable numbers can be left in a wound without producing evidences of their presence. Under varying influences the virulence of bacteria may be greatly increased or diminished, and consequently the dose of any given organism may vary considerably.

The **state of the tissues** in which the organisms are arrested is an important factor also in the question of suppuration. A diminution in the vitality of a part furnishes a soil favorable for bacterial growth. Anemic animals resist inoculation with the aureus much less vigorously than those in health. This is in accord with the well-recognized clinical fact that furunculosis is a sign of a debilitated condition of the system.

Slight injuries appear to favor infection more readily than th severer forms, in which the inflammatory reaction is vigorous an protective in its influence. Osteomyelitis and tuberculosis of th bones find their starting-points in slight bruises in the bones in chi dren who are run down or over-fatigued. Such diseases are nev observed as a complication of simple fractures. The pressure of foreign body may be the source of an irritation which paves th way for a bacterial infection. Obstructions of the secretions, suc as milk in the puerperal breast, are predisposing causes of su puration. Whether the presence of sugar in the blood directly favo the action of the pyogenic cocci is uncertain. It is more probab that the diminished vitality of the system is the favoring elemer Those addicted to the excessive use of alcohol are especially susce tible to infection. A feeble circulation, such as is seen in hyposta congestions, favors a local infection, as does also the impairment the innervation of a part. The healthy peritoneum can absorb lar numbers of bacteria; but when injured in such a way that its pow of absorption is seriously disturbed, the conditions for infection a most favorable.

Racial peculiarities, although they play a prominent part in p disposition to certain diseases, do not exert much influence one way the other on suppuration. The same may be said of locality, althou instances of certain forms of infective inflammation have been credi to certain localities, such as osteomyelitis in Switzerland and Germa Less importance is attached to the season of the year, as an elem in infection, than was given it before the antiseptic era.

The possibilities of auto-infection should always be borne in mi Park has dwelt upon the danger of infection from this source, and importance of due attention to the excretions, particularly those of intestinal canal.

Local Action of Pyogenic Organisms.—When the conditi for suppuration are favorable, if a culture of the staphylococcus injected into the tissues, the bacteria multiply rapidly and invade intercellular substance and the pre-existing cells of the part. The c ditions found in acute inflammation soon present themselves. Exu tion and emigration of leukocytes begin, and enormous numbers of p nucleated leukocytes are found between the connective-tissue fibers

The cocci show a tendency to aggregation in groups, and for more or less continuous mass with the infiltration of leukocytes. the second or third day the granulation-tissue begins to soften in center, as a result of the coagulation-necrosis and consequent brea down of tissue produced by the action of bacteria and the abun exudation. At the periphery of the inflamed mass the coccus leukocyte infiltration continues to spread; the cocci grow in thick umns, with small groups here and there along their borders, w groups separate and grow into the surrounding tissue (Fig. 19). In way local suppuration or abscess-formation is established, and by the tinued growth of the bacteria burrowing of pus may be brought al

There is a marked difference between the action of the staphylc cus and that of the streptococcus. The latter does not possess tendency to promote local suppuration. It creeps rapidly througl

tissues, and produces in this way a spreading inflammation. It exerts a less active peptonizing action upon the tissues than does the aureus. When deprived of oxygen, the peptonizing action comes out more strongly. Consequently, under favoring conditions it might be expected to cause suppuration, and this action it does exert during the later stages of the period of its invasion of the tissues.

The staphylococcus, owing to its mode of growth, tends to remain localized, and produces inflammations with well-defined areas. It is the organism most frequently found in the typical abscess. The streptococcus, although it may cause suppuration, is identified with those forms of inflammation which invade the tissues through the lymph-spaces and vessels. It is found in those septic inflammations which are the result of wounds received during dissections or operations on highly septic tissues. Such inflammations are accompanied by lymphangitic involvement of the adjacent lymphatic glands and by marked constitutional disturbance. The organism gains an entrance into the circulation readily, and where conditions are favorable may multiply enormously, producing that grave form of infection known as septicemia. If its advance has been resisted successfully, it may remain more or less localized, and will then probably produce that type of suppuration known as spreading abscess, or purulent infiltration. These forms of suppurative inflammation are known as phlegmonous inflammation or phlegmonous erysipelas.

Infective inflammation may also terminate in death of the part. This occurs in the more virulent forms of infection, where the protective influence of the serum and the cells is incapable of staying the progress of infection. The toxic substances produced by the cocci are found in great abundance, and destroy the tissues with which they come in contact before suppuration can be established; considerable portions of tissue necrose, and extensive sloughing or gangrene occurs. The rapidly spreading gangrene following complicated fractures or wounds poisoned by splinters of wood or other substances are examples of this type of inflammation, which, fortunately, is rare.

Septic inflammation of light degree may terminate by resolution. This is seen in wounds that have not been treated by careful antiseptic methods, and was common before the days of antisepsis. For a few days the edges of the wound are red and swollen and there is more or less fever. It was formerly considered the type of traumatic inflammation, and was supposed to be essential to repair. Such an inflammation may, however, subside with, at the most, a little seropurulent discharge from the stitch-holes.

Threatening suppuration may be prevented by a prompt use of the knife, which exposes the infected area and enables the surgeon to apply antiseptic agents directly to the infected tissues.

In the more serious forms of spreading sepsis free incisions are indicated, followed by the application of antiseptic poultices, which favor a free flow of fluid from the part, thus enabling the tissues to throw off the virus. Suppuration, it should always be remembered, is Nature's method of ridding the infected parts of the morbid substances. With the formation of pus, liquefaction of the tissues occurs, and with its discharge the "peccant humors" are eliminated from the body.

CHAPTER III.

SUPPURATION; ABSCESS; ULCER; SINUS; FISTULA.

SUPPURATION.

SUPPURATION takes place in the tissues by virtue of the peculi peptonizing or digestive action which the micro-organisms exert up them, and also as the result of the more or less complex chang which occur in them in their efforts to oppose bacterial invasion. is one of the manifestations of the resistance of tissue to the presen of poisons (Thayer). The organism more frequently concerned suppuration is the Staphylococcus pyogenes aureus and other me bers of this group. The points of entrance of these organisms in the body vary greatly. In operative surgery they are introduc directly into the wound on dirty instruments or dressings or by t hands of the surgeon. When they thus gain an entrance in suffici numbers they cause suppuration and prevent healing by first intenti Wounds which have been greatly bruised either by injury or irritat antiseptic agents or prolonged manipulation are more susceptible their action than cleanly cut wounds. The same is true of wounds lips of which are in a state of tension.

Bacteria cannot gain an entrance directly through the cutis v but may find their way through the numerous minute openings of skin, more particularly the hair-follicles and the sebaceous glands, perhaps also the sweat-ducts. This has been demonstrated by Ga who rubbed a large quantity of an aureus culture into the uninju skin of his left arm and produced a carbuncle.

The bacteria also frequently gain an entrance through mir wounds in the skin, and many severe internal suppurations such osteomyelitis trace their origin to infection through this route. child is constantly receiving bruises, and, if the system is enfeeb the pyogenic organisms which abound in dirty clothing may be in lated into these openings.

The nates of oarsmen, particularly when overtrained, receiving abrasions from fric are exposed to infection from the clothing saturated with the products of cutaneous e tion and desquamation. The nasal cavity is usually free from bacteria, but the pha and the mouth contain large numbers of bacteria of a great many varieties, not all of w however, are pathogenic. Pyogenic organisms are frequent in the pharynx, and the mococcus is found habitually in the mouth.

It is due to this cause, probably, that many severe operations, e cially those of the digestive tract, are followed by pneumonia. toilet of the mouth is now becoming recognized as a part of the pr ration of a patient for capital operations. The tonsil has been descr as a "physiological wound," so susceptible is it to infection. Not tonsillitis, but probably also many other forms of internal septic p esses, receive their virus through this gate of entrance. The cer

lymph-glands act as strainers to many of these organisms, and more particularly to the tubercle bacillus.

Many pathogenic organisms find their way into the intestinal canal with food and drink, and many are indigenous. Under favorable circumstances peritoneal infection may occur directly through the intestinal walls. Tuberculous adenitis of the mesenteric glands, tabes mesenterica, owes its origin to infection from this source. Some of the most grave infections are due to a sepsis intestinalis.

From whatever source they are derived, the bacteria exert their pathogenic action only when concentrated at any given point in sufficient numbers. Capillary systems in which the current is not too active favor these conditions, and it is usually at some such point, as, for instance, a capillary loop of the kidney, or one of the vessels of the rich capillary network of the epiphyseal line in long bones, that a cluster or plug of organisms becomes arrested. As the organisms multiply, the material (bacterial proteid) given off by them exerts a poisonous action on the adjacent tissue, resulting in a coagulation necrosis or death of the part with which the virus comes in contact. The irritating substances exert a chemotactic action also upon the wandering cells and leukocytes which presently begin to appear in large numbers, often in columns, and surround the mass of dead tissue. If an abscess is examined at this early stage, there is found in the center of it a cluster of micrococci embedded in a mass of necrosed tissue, the outlines of which may still be discerned, but which forms a more or less transparent zone around them (Fig. 19). Surrounding this mass of

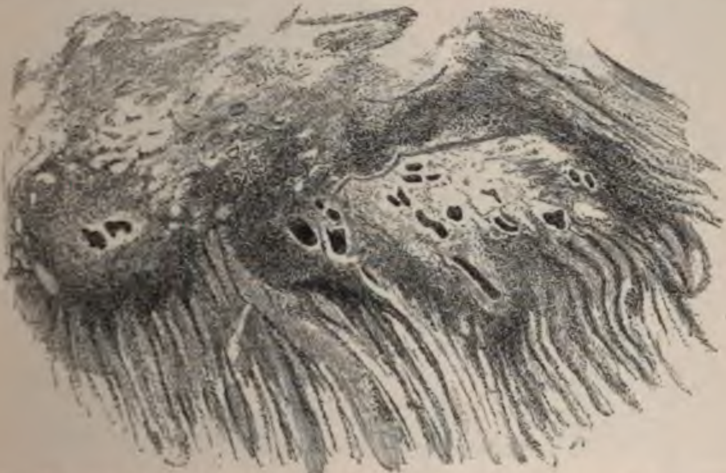


FIG. 19.—Metastatic abscess of kidney: plugs of micrococci in central necrosis, with surrounding cell-infiltration (oc. 3, obj. A) (Warren).

broken-down tissue is a wall of leukocytes. As the abscess grows in size, the leukocytes wander into the necrosed area and mingle with the micrococci. Many of the foremost ranks of the wall of leukocytes are separated from their neighbors by the liquefaction of the intercellular substance, which liquefaction is caused by the peptonizing action of the bacteria. To this fluid is added that which escapes from the adjacent blood-vessels with the exudation. In this way the amount of

fluid material is increased. At this stage the central area is occupie with a semi-fluid mass containing fragments of broken-down tissu leukocytes, and bacteria. Enclosing this is the zone of cell-infiltratic which forms the wall of the abscess and serves as a barrier again further progress of the infection. The inner layer of this tissue co tains bacteria in varying quantities, and when the abscess is "sprea ing," the bacteria are found near the outer margin of the tissue whi then is breaking down before the onward growth of these organisms

The tension of the tissues over some point in the abscess cavi becomes very great from the presence of the enclosed fluid, the pa here are stretched and further softened by necrotic action; the absce "points," and finally breaks, allowing the contents (which are now cream-like fluid) to be discharged. These contents are known as *p*

An abscess may be defined as a circumscribed collection of p The tissue lining the walls of the abscess cavity is called granulatic tissue. This tissue consists chiefly of small round cells with very lit intercellular substance, and is very rich in capillary blood-vess There are numerous polynucleated cells near the surface which breaking down, and about to be thrown off from the surface as p corpuscles. There are also a number of leukocytes with single nuc

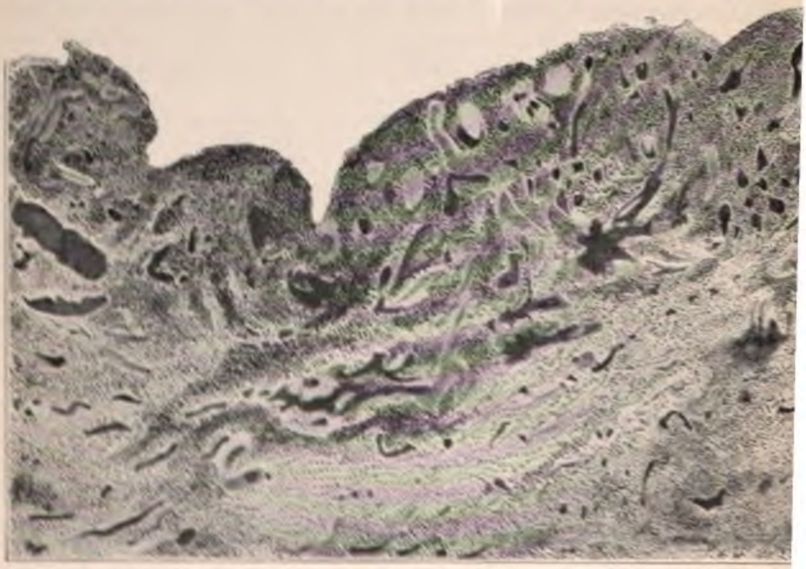


FIG. 20.—Portion of wall of lung-abscess, natural injection (oc. 3, obj. A) (Warren)

and of larger cells, each with a large oval, bright nucleus, which called epithelioid cells. The smaller cells are broken down and sorbed, but the larger cells are active agents in the process of re during the healing of the abscess.

The wall of the cavity is at first lined with pus and shred broken-down tissue, but when this has been discharged and the i surface "cleans off," the lining membrane is found to consist bright-red and highly vascular tissue, the surface of which is dc

with little nodules. These are known as "granulations" (Fig. 20). By this time the cavity has shrunk greatly. The walls approach one another and the granulations grow up from below, and finally only a superficial granulating surface is left, which slowly contracts and is finally covered by epithelium.

Symptoms of Suppuration.—The formation of an abscess is accompanied by a great amount of swelling of the surrounding tissues, which are made tense and brawny by the exudation with which they are infiltrated. A bright-red blush extends even to the surrounding tissues. As the tension increases, the pain becomes acute, and is of a throbbing or a boring character. There is also considerable constitutional disturbance. The advent of suppuration is usually ushered in by a chill or a sudden rise of temperature, which remains high or increases until the pus is discharged.

As pus approaches the surface, the tissues near the center of the inflamed mass become softer, and on pressure with the fingers are said to fluctuate. Near the center of this soft area a white spot appears. At this period the pain is most acute and is lancinating in character, and the febrile disturbance is at its height.

When the abscess breaks and there is a free discharge of pus, both local and constitutional symptoms subside. The blush fades, the skin becomes wrinkled, and the pain disappears. Should the temperature remain high, "burrowing" of pus is to be feared, and the open cavity should be inspected carefully to see if the pus has a free vent. During the healing process and for some time after the wound has healed, the tissues that were involved have a deeper tinge of color than the surrounding normal integuments.

Pus is a yellowish-white substance of the consistency of cream, and in its "normal" condition is odorless and has an alkaline or faintly acid reaction. When allowed to stand, a sediment is formed which, under the microscope, is found to consist almost entirely of *pus-corpuscles* (Fig. 21). There are also found some broken-down tissue-cells, fragments of fibrous tissue, and various forms of bacteria, principally the pyogenic cocci. There is also a certain amount of granular débris, the remains of broken-down cells and blood-corpuscles. The fluid is known as *liquor puris* or pus-serum. It is a pale yellowish fluid, which differs somewhat from blood-serum in containing the products of the decomposition of the tissues during the suppurative process, such as leucin and tyrosin. It also contains peptone. The principal source of the pus-cells is the blood from which the leukocytes migrate to the focus of suppuration. When treated with acetic acid and the various staining methods, these corpuscles are found to contain

FIG. 21.—Pus-cells treated with acetic acid, and crenated red blood-corpuscles (oc. 4, obj. D) (Warren).

several nuclei. This polynuclear condition is not a sign of cell-activ but one of degeneration. Many of the cells, however, when exami in the fresh state, have ameboid movements. The tissue-cells are r resented to a certain extent among the pus-corpuscles, but their num is quite limited. Bacteria are rarely seen in the interior of pus-ce but they are usually found between them floating in the pus-ser Pus may appear very differently according to the character of the fection and the activity of bacterial growth.

The thick creamy pus which forms when an abscess has "ripene (a process which lasts two or three days), is known as healthy or *la able pus.* It has comparatively few bacteria in it.

Ichor is a name given to pus in a state of decomposition. The p cells are few in number and bacterial growth is active, the bacteria decomposition replacing those of suppuration.

Sanies is pus usually mixed with blood, and is also in a state decomposition. These forms of pus are very irritating, and have eit a strongly acid or an ammoniacal reaction.

Cultures taken from any of the above-named varieties of pus o prove to be sterile. This is due to the fact that the organisms h died. Sterile cultures are taken from abscesses of long standing, s as are seen in cases of pyosalpinx, also in the pus from an old empye even when foul smelling. The fetid pus from an ischiorectal absces generally due to the growth of the Bacillus pyogenes fœtidus. thin water-pus taken from the peritoneal cavity oozing from a fr appendicial abscess contains an active growth of the Bacillus communis.

Blue pus is caused by the presence of the Bacillus pyocyaneus. has no special pathological significance.

Orange-colored pus is found often in rapidly spreading forms phlegmonous inflammation. It is due to a deposit of hematoidin crys on the granulating surfaces caused by the presence of extravas red blood-corpuscles in the exudation. It is rarely seen.

Red pus is also a rare occurrence. It is due to the presence bacillus about one-third the diameter of a red blood-corpuscle. cultures in blood-serum have a bright-red color which later change violet. The red pus is best seen on white dressings when first remo It can readily be distinguished from blood with a little practice. allowed to dry upon the dressings, it does not change color, whe blood soon assumes a dirty-brown color.

Tuberculous pus is not considered true pus by many authorities. is a pale chalky fluid, with inspissated cheesy masses and clots of fi floating in it. It contains but a few pus-corpuscles and no pyog cocci. The sediment consists of the fragments of broken-down tis and of a few tubercle bacilli. It is often difficult to find the bacilli, even to obtain cultures of them, but inoculations in guinea-pigs duce a miliary tuberculosis. It is probable that these tubercles developed from sepsis, although the existence of spores in tube bacilli has not yet been demonstrated.

The Microscopical Examination of Pus.—Spread the pus in very thin st over the surface of a cover-glass by means of a platinum wire, and dry it either in the a over a flame. Then, holding the preparation with cover-glass forceps, pass it rapidly

times through the flame, to "fix" it. The preparation is now ready to be stained by any of the various methods which have been devised.

For most purposes staining with a solution of methylene blue is sufficient, for this dye stains sharply not only the nuclei of pus-cells, but most bacteria as well. This solution consists of a mixture of 30 c.c. of a saturated alcoholic solution of methylene blue and 100 c.c. of a 1 : 10,000 solution of potassium hydroxid.

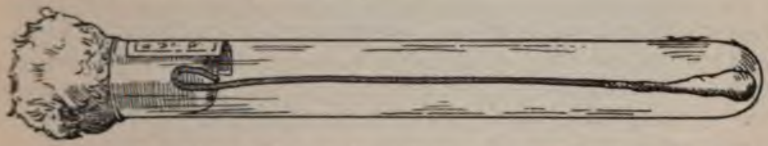


FIG. 22.—Sterilized test-tube and swab for collecting pus and fluids for bacteriological examination (Warren).

In staining, the cover-glass preparation, held in the grasp of cover-glass forceps, is covered with the staining solution and gently heated for a few seconds over a flame. It is then washed in water, dried thoroughly and mounted, stained surface down, in balsam on a slide. If desired, the preparation may be examined without mounting in balsam, by simply placing it on a slide, charged surface down, and drying off the surface of the cover-glass. If this procedure is adopted, it is necessary that there should be a layer of water between the cover-glass and the slide, in order that good optical definition may be obtained.

Pus may also be examined unstained and in "fresh" condition by placing a drop of it upon a slide and then upon this a cover-glass.

If desired, a drop of acetic acid may be run under the cover-glass to bring out the outlines of nuclei.

ABSCESS.

Abscess is divided into two varieties, the acute and the cold abscess. The latter is due to the presence of the tubercle bacillus, and will be considered in the chapter on Tuberculosis.

Acute abscesses may be divided into several general classes according to their situation. They may be superficial, such as boils, subfascial, subperiosteal, or in the bone. Still more deep-seated are those connected with the internal organs, which may be designated visceral.

Abscesses of the skin are among the most common forms. Infection of the skin may be most superficial, or it may penetrate into the subcutaneous tissues, and may give rise to pustules, boils, or carbuncles.

When the micro-organisms penetrate the hair-follicles as far as the sebaceous glands and form a minute focus of suppuration, there results a *pustule*, which may vary in size according to its seat in the upper part of the follicle, in the coil of a sweat-gland, or in the large sebaceous glands.

The **boil** or **furuncle** is caused by an invasion of bacteria either through the hair-follicles or sudoriparous glands to a deeper portion of the skin or to the subcutaneous cellular tissue. The active growth of the organisms is sufficiently extensive in this case to produce a coagulation necrosis of appreciable size which subsequently forms the "core" of the boil. The part most frequently destroyed is the hair-follicle with its accompanying sebaceous gland. The first symptom of a boil is the appearance of a minute pustule situated at the opening of a hair-follicle. Its presence is first noticed on account of an itching sensation which it causes. This is soon followed by an infiltration of the skin which finally extends to subcutaneous cellular tissue. A crust forms on the site of the papule, and on removing this a small quantity

of pus escapes. On introducing a fine probe, it is found to enter to tl depth of half an inch. The boil continues to enlarge for a day or tw and the opening is now sharply defined and circular, and is sufficient large to enable the pus to escape freely. Finally pressure extrudes a sma slough and the inflammation begins to subside, the opening contract and the minute abscess eventually heals by granulation. The pain at first slight, itching being the most prominent sensation. This is r placed later by soreness which is rarely more acute, but is omnipreser owing to the superficial and exposed situation of the inflammato focus. During the period of greatest tension upon the skin there m be severe pain.

Furunculosis is a term applied to those cases in which the patie is afflicted with a succession of boils. Contagion occurs by the sme ing of the discharge over the adjacent surfaces and also by the inocu tion of dried pus by the finger-nails of the patient during scratching other manipulation. In this condition there is an undue susceptibil of the tissue owing to some disordered condition of the system.

Carbuncle is a suppurative and gangrenous inflammation of t skin and the subcutaneous cellular tissue, which begins, like furunc on the surface of the skin and spreads gradually downward and lat ally into the subcutaneous tissue. In its earlier stages of developm the infected area may have the form of a cone, the apex being starting-point in a hair-follicle, sweat-duct, or minute abrasion. T organisms most frequently found in carbuncular pus are the Staphy coccus pyogenes aureus and albus. A state of general debility pla the tissues in a condition to furnish a favorable soil for the growth bacteria. Certain constitutional diseases, such as diabetes, seem quently to be accompanied by carbuncle. The disease is rarely s in childhood. It is most frequently observed in persons over fo years of age. A carbuncle is usually situated at the back of the ne although carbuncular inflammations are occasionally seen upon the and upon other portions of the body. The spread of the infection a it reaches the subcutaneous tissue is horizontal and, later, up tow the surface.

The subcutaneous tissues on the back differ anatomically from those of other portio the body where the skin is thinner. Here the skin is double the thickness of that or inner side of the arms and the abdomen. This integument is held down to the subj fascia by fibrous bands of considerable size. Near the point of origin of these band the columnæ adiposæ, or columns of adipose tissue, in which the hair-follicles of the hairs take their origin. Coils of sudoriparous glands are also found suspended in tissue.

As the suppuration spreads deeply, it seeks a route to the sur through these columnæ adiposæ, and thus gives the characteristic pearance of a carbuncle (Fig. 23). When fully developed, a carbu is characterized by its broad flat base and flattened oval surface ra considerably above the level of the skin. The skin is reddened, perforated at several points with holes of considerable size, from w oozes pus. The skin is extremely tense and red, and the infiltr parts have a density unusual in ordinary inflamed tissue. The sma openings in the center gradually fuse into one or more larger openi through which large sloughs of subcutaneous tissue may be discer

(Fig. 24). Carbuncles may vary greatly in size, some of them being several inches in diameter. In the larger varieties full development is reached about the end of the second week, and the final healing of the wound after the sloughs have been cast off may not be reached for

FIG. 23.—Infiltration of columna adiposa and subcutaneous tissue with pus in carbuncle (Warren).

five or six weeks or even longer. The constitutional condition of the patient varies greatly. In the milder cases there may be little or no fever, but large carbuncles are usually associated with considerable cachexia. When diabetes exists the prognosis is most unfavorable.

FIG. 24.—Diagram of a carbuncle (Warren).

Carbuncle of the lip is a deep-seated suppuration, usually of the upper lip, involving the skin and subcutaneous tissue. It is accompanied by profound constitutional disturbance, and in many cases the prognosis is most unfavorable. This is due to the involvement of the rich venous anastomoses with the cerebral sinuses. Death may occur as a result of both meningitis and pyemia. In one case observed by the

writer there was a general infection by the Streptococcus pyogenes wit pyemia.

The **treatment of boils and carbuncles** is mainly antiseptic. consists in an effort to reach the locality of the growth of the orga isms and arrest its further progress. A boil may be aborted in th way if the treatment is applied early. If the pustule can be se within twenty-four hours from its first appearance, it can usually destroyed by boring with a sharpened piece of wood dipped in pu carbolic acid. In a further advanced boil the infected area should laid open by a crucial incision, so that the acid can be thorough applied. A fully developed boil should be freely opened, curette and disinfected with carbolic acid or peroxid of hydrogen. An an septic dressing may be applied and retained with collodion or an an septic poultice may be applied. If in an exposed situation the b had better be allowed to run its course without incision, as scarring thus avoided.

The treatment of carbuncle varies according to the gravity of t case. In diabetic patients it is unwise to interfere surgically. An septic dressings may be applied, and careful attention should be giv

FIG. 25.—Excised carbuncle. Wound healed in three weeks.

to the constitutional treatment and diet. A rapidly spreading carbu cle in a man of good constitution had better be excised. Two se elliptical incisions include those portions of the skin riddled with p tule. Flaps of skin are then dissected upward and downward u healthy tissue has been reached, and the whole infected area is t excised in one mass. The wound should be disinfected in the m thorough manner and dressed with iodoform gauze, outside of wh a large aseptic absorbent dressing should be applied. Fever and lo inflammation cease promptly, and the wound soon begins to granul It heals rapidly, and leaves a comparatively small scar (Fig. 25).

Antisepsis of the skin of the infected locality should be enjoi upon the patient for some time after the healing either of boils or c buncle, as the tendency to recurrence is occasionally very obstin

This can be accomplished by daily ablutions with soap and water and the use of alcohol externally. The patient should also be directed to cleanse the hands and nails thoroughly each time after dressing the sore. Frequent changes of underclothing should also be made, so that all possible sources of infection may be avoided. Fowler's solution of arsenic should be administered internally.

Subfascial abscess includes those forms of suppuration found in the intermuscular septa or beneath the fasciæ which enclose the muscles. They may arise from a blow or a muscular strain or as the result of a lymphatic infection. Suppurative adenitis is a frequent source of such abscess in the neck, in the axilla, and in the fasciæ. An inflamed bursa may also be the source of such abscesses.

The anatomical arrangement of the fasciæ and the spaces which they enclose often determines the route these abscesses pursue. In the neck, for instance, is found the deep cervical abscess, which forms in the upper triangle in one of the lymphatic glands situated near the angle of the jaw. This abscess burrows downward, sometimes to the anterior mediastinum, owing to its inability to penetrate the deep layer of the cervical fascia. A subfascial abscess may also take its origin from an inflammation arising in an adjacent organ, as the kidney, giving rise in this case to a perinephritic abscess. Suppuration may occur as the result of a strain or rupture of some internal muscle, such as the psoas magnus.

The earliest symptoms of such deep abscesses are chiefly of a subjective nature. At first a slight local edema without swelling or redness may be seen. In a few days there is evidence of deep-seated infiltration, and the part becomes tender on pressure. As the inflammation approaches the surface, all the symptoms become more marked. At this time the skin is tense and red, and the subjacent tissues are swollen and infiltrated. There is early fever, and an examination of the blood will show a marked leukocytosis.

The **treatment** of these abscesses, often large and deep-seated, is of much importance. Once the diagnosis has been made, they should be opened in order to prevent extension of the suppuration and unnecessary destruction of tissue and perhaps fatal systemic infection. Such abscesses should always be opened with strict antiseptic precautions, firstly because their contents may prove to be sterile, and secondly because a mixed infection might add to the virulence of the inflammatory process. An incision should be made large enough to enable the operator to reach all parts of the interior of the abscess-cavity. The fluid contents having been thoroughly evacuated by pressure, douching, or sponging, the walls should be thoroughly curetted in order to remove the abscess-wall or that portion of it, at least, which contains the pyogenic organism. The remaining cavity should then be disinfected thoroughly with carbolic acid 1 : 100, corrosive sublimate 1 : 1000, or peroxid of hydrogen, and packed with iodoform gauze. Occasionally an abscess-wall may be so accessible as to be reached and dissected out by the knife. Under these circumstances it would be possible to obtain healing by first intention. It is better in doubtful cases to pack with gauze and bring the walls together a day or two later by tying the provisional sutures.

If it is not possible to disinfect the cavity thoroughly, then drainage in some form should be used. Rubber drains are most useful for this purpose, and can be packed in place with gauze. If it be desirable to keep the edges of the wound moist, large antiseptic poultices may

be used. They should be changed every two or three hours when the discharge is free and foul. Corrosive sublimate when used in a poultice should not be strong, 1 : 10,000 being sufficient. Sulpho-naphthol 1 : 500 or creolin may be employed as useful substitutes. In deep-seated abscess, involving internal organs, such as perinephritic abscess, the operation required is one of major importance.

Panaritium or **felon** is another example of subfascial abscess Its origin varies, for it may begin in the skin, in the subcutaneou tissue, in the tendons, or in the periosteum. The infection take place through some skin-abrasion, callus, blister, or punctured wound Cooks, butchers, and dissectors are liable to these infections, thei hands coming in contact with putrescible substances. The anatomica arrangement of the connective-tissue felon on the palmar surface o the hand and fingers is such that it runs perpendicularly inward to th palmar fascia or to the sheaths of the tendons, and the infective mate rial is for this reason readily directed to the deeper parts. The felo is usually found at the end of the fingers. It begins with an intens throbbing pain and gradually increasing swelling. There is more c less fever and great suffering from the throbbing character of the pai The pus is confined either beneath the periosteum or the tendon c fascia, and if not evacuated may spread and break into the tendc sheaths, and thence extend into the palm of the hand. This extensic occurs most readily in the sheaths of the tendons of the thumb ar little finger, which are continued into the palm of the hand and benea the annular ligament.

Abscesses which form under the palmar fascia are known as *palm abscesses*. The infection may be transmitted from the fingers, as abo stated, or it may occur through bruises, wounds, or blisters in the sk of the palm of the hand. Like the felon, this abscess is liable to spre rapidly, and if it is neglected, pus may in a day or two be found abo the annular ligament, and may even dissect apart the deeper structu of the forearm. When a palmar abscess reaches its stage of full c velopment, the whole hand is involved, the integuments are grea swollen, the natural furrows of the hand disappear, the fingers : flexed, and the hand assumes a claw-like aspect.

The **treatment** of abscess of the fingers and the palm of the ha should be most prompt, as delay may permit disorganization not o of the soft parts but even of the bones and joints of the hand. case of felon, the knife should be carried down to the bone and clean to the end of the finger-pulp. In making incisions into the pa care should be taken to avoid the vessels of the palmar arch. Brool method of making incisions along the folds of the palm (Fig. 26), tu ing back a large flap, and curetting the subjacent abscess is an impro ment on the older methods. By carefully determining the seat of pus the knife may be used without fear, and when the pus-cavity o has been opened, its various ramifications should be followed to t farthest point of extension. After a prolonged bath in some wa antiseptic solution the hand should be placed in a large antise poultice reaching nearly to the elbow. The arm should either placed upon a splint, or if the case is serious the patient should placed in bed and the arm allowed to lie upon a pillow, the h

being very slightly elevated. Serious contraction of the finger may occur, due to sloughing of the tendons or the formation of cicatricial bands.

Phlegmonous inflammation is a term given to the spreading forms of suppuration, such as are usually produced by the invasion of the streptococci. In these cases all the signs of acute inflammation are present and the area involved is extensive. The connective-tissue spaces and the lymphatic vessels are the routes through which the

FIG. 26.—Brooks's incision.

virus spreads. The streptococci do not cause suppuration at first, but as they grow they exert a widespread poisonous influence upon the tissue. If an incision is made into the part during the early stage of the process, there is set free a more or less clear yellowish fluid which may contain a few pus-cells or flakes of fibrin. Sloughing begins early, and gradually suppuration is established. The skin is freely loosened from the fascia by the death of the intervening structures, and the muscles are often dissected apart. Such inflammations are often the sequel of infection starting as a felon or palmar abscess. Frequently, however, the virus spreads far too rapidly for suppuration to become established at these points, and the whole arm quickly becomes involved. The skin is hard and brawny at points, and covered here and there with bullæ. The whole limb is edematous. In some of the worst forms the subcutaneous tissue becomes emphysematous, due to the presence of gas given off by the development of some of the saprogenic organisms. Such a type approaches that form of septic inflammation known as malignant edema, due to infection with the bacillus of that name. Cases of true malignant edema are, however, extremely rare.

The constitutional disturbance in phlegmonous inflammation is usually profound, and may develop into true septicemia if the streptococci gain an entrance into the system in sufficient numbers.

A good example of phlegmonous inflammation is seen in a case of compound fracture of the leg which has become septic. In such a case the soft parts extending from the ankle to the knee may become involved in the sepsis. The most severe type of this inflammation is phlegmonous erysipelas.

Pus frequently accumulates in large quantities in the previsceral or postvisceral spaces of the neck (cervical abscess), in the subdiaphragmatic region, around the kidney (perinephritic abscess), the liver, the

gall-bladder, the pancreas, the appendix, and the uterine adnexa. Ab scesses in these regions are of special interest to the surgeon, and ar described in their appropriate places.

Diagnosis.—The symptoms of abscess already enumerated suffic to make the diagnosis of abscess easy in the great majority of case: Abscess has, however, been mistaken for a great variety of disease: One of the most serious errors, and one which has frequently bee made, is to mistake aneurysm for abscess. The gush of arterial bloo which follows plunging the knife into such a swelling leaves no furth doubt as to the diagnosis. Various tumors, such as sarcoma or fatt tumor, may be mistaken for abscess.

An abscess burrows in the direction of least resistance, but its spread is not due to pres ure alone, but to the infection produced by the bacteria. Dense fasciæ are, howeve usually sufficiently strong to prevent infection through them except when in contact with t most virulent poisons. It is not good surgery to count upon the absorption of pus, for on very small quantities of it may disappear in this way. Minute or miliary abscesses m disappear entirely by absorption, but a collection of pus sufficiently large to be recogniz clinically is a focus of infection and a source of danger even after the death of its bacter Many abscesses which have been supposed to be absorbed break into the intestinal can Many appendiceal abscesses are cured in this way.

Treatment.—In the spreading forms of inflammation the mo prompt intervention on the part of the surgeon is demanded. T indications are to reach the micro-organisms at all points where th are growing actively in the tissues and to attack them with all the r sources of antiseptic methods. Small incisions may only aggrava the mischief by introducing new organisms. Free incisions therefo are indicated, and pus should be followed relentlessly to the farth point of the suppurating tissue. When the area involved is very e tensive, it may be preferable to make multiple incisions, so arrang that drainage may satisfactorily be obtained and that the scar may so situated as not to interfere with the function of the part. A sloughing tissue should be excised or scraped away, all pus-cavit curetted, and all exposed surfaces disinfected by free douching w antiseptic washes. Large antiseptic poultices are the best form dressings, as they favor a flow of serum from the part, and thus Nature in an attempt to wash away the virus. Frequent antisep baths also are useful for this purpose, the limb being allowed to rem for an hour at a time in some mild antiseptic fluid.

The internal treatment consists in the free use of alcoholic stin lants. Strychnin and digitalis may be administered when the pulse dicates a feeble action of the heart. The patient should be kept in b and the limb placed in a comfortable position on a pillow. Opium n be given to relieve pain and to ensure rest.

ULCER.

An ulcer is a solution in continuity of the skin or the mucous me brane which shows no tendency to heal. The term implies that wound or granulating surface is stationary or enlarging, and that it developed by a death of the part piecemeal. It owes its existence an excess in action of the retrograde changes over those of rep An open granulating wound is not an ulcer, but it may become on

the granulations begin to break down and the edges begin to melt away. A large granulating wound that comes to a standstill owing to the inability of the parts to cover so extensive a surface is called an ulcer. An example is the unhealed end of an amputation stump. Ulcers may be classified according to their mode of origin. A large number of ulcers result from infection producing granulation-tissue which is of low vitality and easily breaks down. The diseases which most frequently give rise to ulceration are syphilis, tubercle, leprosy, glanders, and cancer.

Ulceration may be produced by disturbance in the circulation or in the nerve-supply. Obliterative changes in the arterial system give rise to local anemias which are incompatible with the life of the part, and thus cause ulceration. Examples of such changes may be found occasionally in the stomach and duodenum. Passive hyperemia gives rise to stagnation, softening, and degeneration, and pressure may cause stasis and necrosis. Varicose ulcers and decubitus are clinical examples of such conditions. Disturbance in the nerve-supply gives rise to a long train of trophic disturbances, among which is ulcer. Local friction may cause abrasions which develop into ulcers.

The surface of an ulcer is usually covered with a layer of more or less broken-down tissue mingled with exudation. It may be in a state

FIG. 27.—Chronic ulcer of the leg (Warren).

of coagulation necrosis and form a rind which covers the granulation-tissue below it. In a section of an ulcer this layer of granulation-tissue is about the thickness of the adjacent cutis. The cells of which it is composed are largely polynucleated leukocytes and epithelioid cells with comparatively little intercellular substance. This layer is more or less defined owing to the crowding together of the round-cell elements which characterize it. Beneath this layer a more transparent tissue is seen containing a larger quantity of intercellular substance composed

of pale transparent fibers and a number of fusiform cells. Deeper still the tissues become more fibrous, partaking more of the character of cicatricial tissue. From this layer blood-vessels are given off which run more or less vertically upward and lose themselves in a capillary network near the surface of the ulcer. The base of the ulcer consists, as will be seen from this description, of two principal layers, a soft granulating surface which can easily be scraped away, and a denser tissue beneath it which remains after curetting. This appears to the naked eye as a dense whitish layer bleeding at numerous points. It serves as a sort of fascia separating the morbid tissue from the surrounding healthy parts (Fig. 27).

The edges of old ulcers are raised somewhat above the level of the base, and are made more prominent often by the thickened layers of epidermal tissue. Such ulcers are said to have callous edges, and the thickened masses of epidermis appear to be an ineffectual effort upon the part of Nature to bridge over the chasm. Beneath the epidermis lies the papillary layer. The papillæ are more or less elongated and contain a rich vascular and cellular tissue and considerable numbers of granules of blood-pigment, which may be found also in the rete mucosum. The margins of the ulcer are sometimes undermined. This is particularly characteristic of tuberculous ulcers. Under these circumstances its edges are red and infiltrated, and often have a bluish tinge.

Varicose Ulcer.—This is the most common form of ulcer seen by the surgeon. It is found upon the legs, usually at the junction of the middle and lower thirds. Its origin is due to the presence of varicose

FIG. 28.—Varicose ulcer.

veins which produce a stagnation or passive congestion of the capillary districts involved. The surrounding tissues become saturated with a thin serum which oozes through the walls of the capillaries and small veins. This causes edema of the parts. With the serum there is an exudation of the red blood-corpuscles, which break down and leave an extensive pigmentation or bronzing of the parts. The nutrition of the tissues is enfeebled and the edema causes a softening of them. A

small abrasion occurs finally as the result of friction or some slight trauma, or a thrombosis of one of the superficial veins produces a slough, and the minute wound thus made is unable to heal. Granulations form, but soon break down, and the condition of ulceration is established. The surrounding parts are infiltrated and more or less infected with organisms, and are further softened by a continuation of the inflammatory process now developed. These ulcers enlarge gradually, and at times an acute inflammation may supervene, accompanied by phlebitis of some of the larger veins. Small abscesses form, which break but do not heal. When the local inflammation subsides, the original ulcer has become greatly enlarged. These varicose ulcers are occasionally of great size and may even girdle the limb (Fig. 28). When neglected, as they often are in aged or infirm people, who are unable to submit to treatment, they become extremely foul and are covered with a rind of necrosed and decomposing tissue.

Decubitus or **bed-sore** is also produced by obstruction to the circulation by direct pressure upon the part affected. Bed-sores occur in individuals whose circulation is enfeebled by disease or old age, and appear beneath the bony prominences upon the posterior aspects of the pelvis and inferior extremities. A slough is formed from the venous stasis, and around this ulceration takes place, which may penetrate to the bone. Such bed-sores are liable to occur at parts deprived of their nerve-supply, as after injury to the cord in fracture of the spine. They are due to the immobility of the part and the lack of pain, and also to the absence of innervation by the trophic nerves.

Ulceration may also be caused by the pressure of splints (*Splint-sores*).

A characteristic of ulceration from absence of innervation is the so-called *mal perforans*, which is found frequently associated with locomotor ataxia. It is a sharply-cut circular ulcer developing upon the sole of the foot, is deeply excavated, often involving a joint, and is surrounded by an overhanging border of thickened epidermis. It is probable that this ulcer, like those occurring after injuries to the spinal cord, is principally due to pressure. Ulcers are named frequently according to some prominent clinical symptom associated with them.

An **inflamed ulcer** is one which develops with the signs of more or less acute inflammation, such as occurs often in the life history of varicose ulcers.

Erethistic ulcer is one the great sensitiveness of which persists. It occurs in old ulcers of bone or in the neighborhood of some very sensitive organ, such as the anus.

Ulcers may be *fungous*, owing to the presence of exuberant and edematous granulations. Tuberculous ulceration often presents this appearance.

Hemorrhagic ulcers are seen in scurvy. *Torpid* ulcers are seen in individuals suffering from cachexia. The granulations are pale, and the secretion is thin and watery. Tuberculosis and scurvy are diseases in which this type is most frequently seen. A *callous ulcer* is one which has remained without material change for a long period of time. The surface is dirty, and it secretes a thin mucopurulent material. The edges are raised considerably above the surface, and the skin

adjoining is indurated and immovable. Old varicose ulcers often present this type.

Phagedenic ulcers are those which spread with great rapidity. The edges and base have an appearance as if gnawed by a rodent Such ulcerations are often gangrenous in character. These appearances are found also in ulcers which have been treated with irritating applications. A chancre occasionally becomes phagedenic, and wher in this condition is an unusually obstinate affection.

The Treatment of Ulcers.—Varicose ulcers are best treated by rest and elevation of the part. In the majority of cases they will hea under these circumstances. This method of treatment is hard to carry out, as these ulcers occur in that class of patients which cannot afford the necessary time. When it is necessary to treat the case as a ambulating one, the hyperemia may be relieved by bandaging or plasters. Rubber bandages are useful for this purpose, as they can b applied even by the most ignorant, and can be kept clean. The band age should be allowed to remain on in the day-time only. Strappin with strips of diachylon or rubber plaster is a good substitute, and ca be used in the milder forms of ulceration, the plaster being change every few days. Very foul ulcers must be treated by rest in bed an the local use of antiseptic poultices. Such poultices can be made b soaking absorbent cotton or gauze in solution of boric acid of th strength of 2 per cent., or in phenyl 1 : 500. Cleansing washes wit peroxid of hydrogen or carbolic acid or chlorinated soda favor th restoration of a healthy granulating surface. If it is desired to app a dry dressing, iodoform or aristol may be dusted over the surfac These can be followed by the use of pure zinc ointment, which forn a protective layer not easily absorbed by dressings, and the part is th kept from scabbing.

Painful ulcers are not amenable to any one form of dressing. Pou tices are complained of bitterly as being too "drawing." Some ne tral ointment or one mixed with cocain hydrochlorate, 12 grs. : ℥j, oft gives relief.

Indolent ulcers are often stimulated by the application of balsa of copaiba or Peru. Tincture of myrrh, ʒj : ℥j of water, has a ton effect upon the granulations. Weak solutions of tincture of iodin ha an alterative effect upon such ulcers.

Many ulcers owe their inability to heal to the firm adhesion of t surrounding integuments to the parts below. Much benefit has be obtained by lateral incisions which release the edges and permit cicatricial contraction.

Large ulcers are best treated by Thiersch's method of skin-graftin After this operation upon a varicose ulcer the patient should be ca tioned not to use the leg too soon, as the cicatricial tissue formed und the grafts readily breaks down. A rest of several weeks is indispe sable for the permanency of the cure.

FISTULA.

A fistula may be defined as an abnormal opening into a norm cavity or organ, or as a long narrow channel indisposed to heal. T

latter condition is usually called a *sinus*. The term "fistula" is applied to congenital openings or defects as well as to those which result from abscess. The inflammatory sinus or fistula is similar in character to an ulcer—that is, it represents a wound which has no further tendency to heal.

A sinus may be due to the inability of the parts to complete cicatrization, owing to the presence of a foreign body, such as an infected stitch or ligature. The locality of the wound may be such that unavoidable movements prevent the deeper portions of the wound from healing. A fistula is generally caused by the escape of the physiological secretions or excretions, such as saliva, urine, or feces. When pus has burrowed for a considerable distance beneath the skin, and a large granulating surface has been established, the mere shape of the cavity is in itself an obstacle to cicatrization, as the secretions have an opportunity to escape. Such sinuses are often due to the presence of tuberculous granulations.

Treatment.—Superficial sinuses should be laid open freely and their areas curetted. A careful hunt should be made for infected ligatures. These can often be secured by a crochet needle or a fine curet. Complete extirpation of small fistulæ is sometimes possible, and under these circumstances union by first intention can be obtained. With careful antiseptic precautions this method can be carried out in cases of *fistula in ano*, which are usually tuberculous. When it is not desirable to use the knife, medicated injections can often be used to advantage.

Among the solutions which can be employed for this purpose are: tincture of iodin used in full strength or more or less diluted; carbolic acid (1 : 200), or phenyl (1 : 250). A 10 per cent. emulsion of iodoform in glycerin, and Krause's emulsion, which also contains gum arabic and carbolic acid, are valuable remedies. Fistulæ remain often for many months after abdominal operations. These are due either to infected ligatures or to the communication of a sinus with the bowel or the Fallopian tubes. These fistulæ often eventually heal spontaneously. If it is decided to operate upon them, they should either be curetted with great care, so as not to open the peritoneal cavity, or an opening should be made near them into the peritoneal cavity, which should then be walled off. The track of the sinus or fistula can then be traced to its source, and the diseased tissue can often be excised.

Attention should be given in all cases to the general condition of the patients and their surroundings. A chronic fistula will often heal after some intercurrent disease, such as scarlet fever or typhoid fever. A thorough change in the habits of the patient may also bring about the same result.

CHAPTER IV.

SURGICAL PATHOLOGY OF THE BLOOD.

THE examination of the blood throws so much light upon the condition of surgical patients as to make it a useful rule that every patient's hemoglobin shall be tested once a week (Mikulicz). This is done partly to watch the progress of patients after bloody operations, and partly to ascertain whether it is advisable to operate upon patients already very anemic.

Blood-regeneration After Operation.—1. Mikulicz finds that the length of time needed for full restoration of the blood to normal depends on: (*a*) the amount of blood lost; (*b*) the age and nutrition of the patient (those at the extremes of life bear hemorrhage badly); (*c*) the existence of other diseases (cancer, tubercle, typhoid); (*d*) the treatment.

Other conditions being favorable, he finds that a loss of

Under 1 per cent. of the blood-mass is made up in from 2 to 5 days.
From 1 per cent. to 3 per cent. of the blood-mass is made up in from 5 to 14 days.
From 3 per cent. to 4 per cent. of the blood-mass is made up in from 14 to 30 days.

Few surgical operations involve a loss of over 3 per cent., and accordingly in a normal adult individual under favorable conditions we expect the blood to be normal within two weeks from the time of operation. If it is not so we suspect some deeper cause for the delayed regeneration—*e. g.* cancer. Bierfreund noticed that after operations for malignant disease the blood does not begin to be regenerated until considerably later than after other operations—a week later on the average—*and that it never reached as high a point as it had before operation.* This assertion of Bierfreund's, based upon many cases watched during long periods, is all the more extraordinary because some of his cases made a marked gain in weight and appeared to be greatly improved in other respects after the operation. So far as I know there has been neither confirmation nor contradiction of Bierfreund's data.

Diagnosis.	Per cent. Hb. before operation.	Per cent. Hb. after operation.	Loss.	Time elapsing before Hb. begins to rise.
Malignant tumors without complications.	68.5	53	15.5	23 days.
Very large or rapidly growing tumors.	56.6	38.4	18.2	27.8 days.
Tumors with softening or marked disturbance of function.	57.5	39.7	17.8	27 days.
				Average, 25.9 days.

In 72 cases of malignant disease Bierfreund noted the percentage of hemoglobin daily after the operation to discover how many days

elapsed before the hemoglobin began to rise. In ordinary operations the blood begins to be regenerated in from five to twenty days. The table given on page 80 shows the conditions found in 72 cases of malignant disease.

2. Mikulicz makes it a rule never to operate on a patient whose hemoglobin is under 30 per cent. This gives him a standard up to which patients must be brought by treatment and rest before he will subject them to further loss of blood. Surgeons would do well, in many accident cases where much blood has been lost, to assist their judgment as to operating or waiting by some objective test like Mikulicz's 30 per cent. of hemoglobin.

Importance of Blood-examination in Accident Cases with Shock or Hemorrhage.—1. How often one hears the question discussed in the accident room of any hospital whether to operate at once or wait till the patient has got over the "shock." The question is *not* often asked (far less answered) whether the "shock" is simply or largely anemia (cerebral and general) from loss of blood, or whether it is of nervous origin—*i. e.*, due to concussion, compression, etc. The right decision of this question is of great importance, for if the "shock" means anemia, transfusion may be indicated, while in a condition of cerebral concussion or compression transfusion will probably do harm. An examination of the blood enables us in certain cases to decide such a question. That is, if the number of red cells is considerably diminished—3,500,000 or less—and if the patient is known not to have been previously anemic, the "shock" probably means hemorrhage.

2. Aside from the question of whether any hemorrhage has taken place, the blood-count may enable us to gauge approximately the amount of hemorrhage. Here it should be remembered, however, that *immediately* after hemorrhage the count may be normal, since only the amount and not the quality of the blood is affected. Within a few hours, however, fluid is absorbed from the tissues into the vessels, and then the amount of anemia is indicated by the blood-count.

3. Internal or concealed hemorrhage in obstetric cases, extra-uterine pregnancy, ruptured aneurysm, laceration of the spleen, kidney, liver, etc., can sometimes be diagnosed by the blood-examination. A man recently entered the Massachusetts General Hospital with acute pulmonary symptoms resembling pneumonia, and died before any diagnosis could be arrived at. The point inconsistent with pneumonia was the low blood-count—3,324,000 red cells with 33 per cent. of hemoglobin—and this in a man previously well and not anemic should, I think, have suggested hemorrhage somewhere. Autopsy showed a ruptured aortic aneurysm.

In the diagnosis between pus-tube and hematocele, between hemothorax and pleurisy, I have found the blood-count useful in a similar way.

Abscess and Deep-seated Suppuration.—Almost all acute and subacute suppurative processes in any part of the body manifest themselves in the peripheral blood by an increase in the number of polymorphonuclear leukocytes. It matters not whence the blood is taken, whether from a part near the suppurating point or at a distance. For instance, in a felon the blood from the ear shows as great a leuko-

cytosis as that from a finger next the one affected; and in suspecte middle-ear abscess blood from the ear shows the same number o leukocytes as that from the finger.

1. The degree of leukocytosis is *independent of the amount of pu* A felon may raise the leukocyte-count as much as an empyema.

2. An increasing leukocytosis points to a spreading process, an may be the only evidence of it. In several cases of appendicitis wher the subsidence of pain, tenderness, temperature, and pulse-rate seeme to point to a subsiding process, but where the leukocyte-count steadil rose, the subsequent operation has proved the indications given by th blood to be correct. In this connection it should be stated that leukocytosis-*chart* showing the increase or decrease from day to day i as much more valuable than a single count, as a temperature-chart more valuable than a single temperature record. It is the rise or fa of the count that oftenest helps us in diagnosis, not the single count.

3. Occasionally leukocytosis is absent despite the presence of considerable quantity of pus. This is a rare occurrence, but when does occur, is of considerable importance. It happens:

(*a*) In cases in which the bacteria in the pus have died.

(*b*) In cases where the pus is very thoroughly walled off.

Either of these conditions means that the process is at a standsti and that the pus is acting simply as a foreign body and not as a cent of infection.

(*c*) In fulminating cases of extreme severity in which the patie succumbs without offering any considerable resistance to the action the infection. For example, in 6 cases of rapidly-fatal general pe tonitis I have found the leukocyte-count normal. In 68 other cas of general peritonitis and in hundreds of other suppurative affections have never failed to find leukocytosis except on the conditions ju mentioned in (*a*) and (*b*) above. The failure of the leukocytes to rea in fulminating septic cases is similar to their behavior in the worst cas of pneumonia, diphtheria, and some other infections. Generalizing the facts, it appears that:

I. In the very mildest and the very severest cases there is no leuk cytosis.

II. In the vast majority of the whole range of cases—*i. e.*, those moderate severity—leukocytosis appears.

In other words, it appears as if leukocytosis were present whene there is a hard fight between the attacking infection and the resisti powers of the system—*i. e.*, in over 90 per cent. of all cases; while there is an overwhelming victory either for the system or for the inf tion, the leukocytes are not multiplied.

4. When drainage is established and free exit given to the pus of abscess, the leukocyte-count usually falls rapidly to or nearly to norm As soon as a wall of granulation-tissue is established between t abscess-cavity and the tissues in which it is situated, the leukocy become normal and remain so, provided the drainage is free and su cient, even when the amount of pus discharged is large. If this w of granulation-tissue is broken down by curetting, probing, or *even the removal of stitches*, the leukocyte-count will rise again. Pocketi of pus or anything approaching it is shown by a similar rise.

5. Other things being equal, we get the greatest degree of leukocytosis in the most virulent infections well resisted by the system and independent of the number of cells in the exudation. A general peritonitis, showing only turbid serum and fibrin-flakes as a product, may produce as high a count as one in which the abdomen is full of thick pus. A gangrenous appendicitis or a diphtheritic endometritis may raise the count higher than an abscess containing quarts of pus. Not the product but the violence of the infection governs the amount of leukocytosis.

Average cases of appendicitis, abscess, or pus-tube show from 15,000 to 30,000 leukocytes per c.mm. Counts larger than this mean a case of the greatest severity. Catarrhal appendicitis does not raise the count above 15,000.

6. The count of leukocytes is of especial value in cases of deep-seated suppuration, such as osteomyelitis and hepatic or perinephritic abscess. In the latter affections I have repeatedly seen the diagnosis suggested by the leukocyte-count at an early stage of the disease, when practically no pain or fever was present.

Purulent accumulations in a cerebral sinus following middle-ear trouble sometimes show themselves through the blood-count when there is nothing else to suggest the diagnosis. The differential diagnosis between suppurative and non-suppurative pelvic disease in women is sometimes materially aided by the positive or negative indication given by the blood.

In many surgical cases the elevations of temperature following operation appear sometimes due to "nervousness" or other mental disturbance. In such cases the blood-count is unaffected, while if the temperature is due to sepsis or deficient drainage, the leukocytes are increased.

Other affections which may cause symptoms suggesting pus, but which do not raise the leukocyte-count, are (*a*) the various colics—intestinal, uterine, hepatic, renal; (*b*) typhoid fever, in which resemblance to appendicitis is sometimes puzzling; (*c*) floating kidney; (*d*) fecal impaction or simple constipation; (*e*) ovarian or pelvic neuralgia; (*f*) an attack of grippe, or malaria occurring during convalescence from a surgical operation. These complications may cause a great deal of anxiety from the similarity of some of the symptoms to those of severe sepsis, but neither of them affects the leukocytes; [the detection of the malarial organism is a valuable bit of evidence]. (*g*) Serous pleuritic effusions do not raise the leukocyte-count appreciably in the great majority of cases. Purulent pleurisy [empyema] almost always does.

Tuberculosis.—Pure tubercular infections uncomplicated by pyogenic organisms do not affect the blood to any extent. The only exception to this is tubercular meningitis, which sometimes is and sometimes is not accompanied by leukocytosis, the reason for this variation being as yet unknown. "Cold abscesses" which have been opened, and so infected with pyogenic cocci, show a leukocytosis at once. In hip or spinal tuberculosis an increasing leukocytosis means either abscess-formation or an increased activity in the tubercular process.

Tubercular peritonitis can be differentiated from other varieties of peritonitis by its normal blood-count.

Malignant Disease.—The differential diagnosis between malignant disease on the one hand and tuberculosis or abscess on the other is sometimes greatly assisted by the examination of the blood.

As between malignant disease and abscess or tubercle, the presence of marked deformities in the red cells, or of nucleated red cells, favor malignant disease. Only occasionally in the severest forms of sepsi or tuberculosis do we find these changes in the red corpuscles, an then always associated with great anemia; while in malignant diseas they are more often present, even without extreme anemia. Positiv evidence is, however, of far greater value than negative in such case since the red cells are often not affected in cancer until the later stage are reached.

The leukocytes in perhaps the majority of cases of early cancer ar not increased in number, though the polynuclear varieties may be in ex cess, a fact of the same significance as an increase in the whole numbe

The cases in which the total count *is* increased are usually, thoug not always, those in which the new growth is extensive and rapid spreading, so that its presence could be determined without the troub of making a blood-examination.

Thus the majority of cases of early mammary, gastric, and labi cancer show no blood-changes.

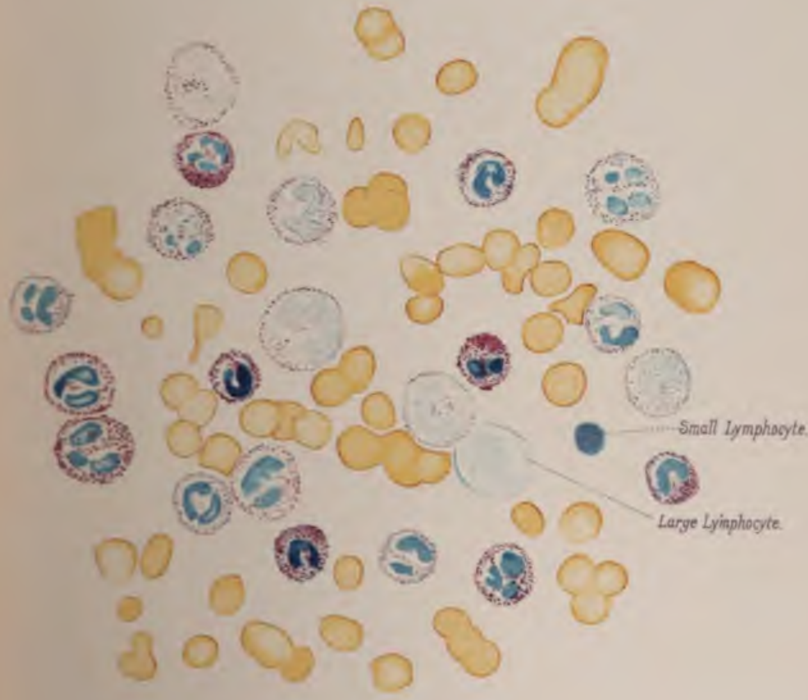
Between cancer and tubercle the presence of leukocytosis poin toward the former, while its absence is consistent with either diagnos The importance of the red cells in this question has already be mentioned.

Between cancer and abscess the leukocytes do not help us, exce that if there is no increase it is probably *not* abscess. In the presen of a leukocytosis we can sometimes get some aid in the diagno between cancer and abscess by an examination of the amount of fib seen in the microscopic field as a drop of blood slowly dries betwe a slide and cover-glass. Fibrin is usually increased in abscess, and r in cancer. Deformed or nucleated red cells would incline us tow the diagnosis of cancer.

Sarcoma is much more frequently accompanied by leukocyto than cancer is. This is especially true of osteosarcoma and re sarcoma. In these affections the counts may run very high, even 100,000 per c.mm. Between osteosarcoma and tuberculosis the pr ence of leukocytosis favors the former, and its absence the latter. have in 2 cases seen a sarcoma of the left kidney mistaken for leu mia, on account of the resemblance of the tumor to an enlarged spl and the great increase in the number of white cells. Of course, *kind* of white cells that are increased differs absolutely in the t cases, and a glance at the stained specimen will settle the diagno but without the stained specimen no diagnosis between the two af tions is possible in all cases. (See Leukemia.)

Leukemia.—Within two years the writer has seen a well-kno surgeon cut down upon a leukemic liver to make sure that it was kemic. This is absolutely inexcusable. The diagnosis of leukemia be made with absolute certainty by the blood-examination alone, and

PLATE 4.



Leukocytosis (60,000): coverslip specimen; Ehrlich's triacid stain. The red corpuscles are stained yellow; all the others, except those labelled, are polymorphonuclear neutrophiles.

been so made in this case. Any case with chronic enlargement of the spleen or lymphatic glands demands a careful blood-examination, with the aid of which no diagnosis in medicine is easier than that of leukemia.

The confusion of leukocytosis with leukemia, although their difference has been frequently pointed out, is still perpetuated through the carelessness of text-book writers. The distinction lies not in the number of leukocytes nor in the duration of the increase (since leukocytosis not infrequently shows a higher count than leukemia, and may last longer), but in the *kind of leukocyte increased.* In leukocytosis only the polynuclear forms are increased; in leukemia it is the lymphocytes or myelocytes that make up the bulk of the increase. In the fresh specimen examined between slide and cover-glass or in the Thoma-Zeiss counting-chamber, the distinction of the different kinds of leukocytes is not practicable. Only in the stained cover-slip preparations can the differences be properly seen. (See Plate 4.)

Lymphatic leukemia sometimes causes only a moderate swelling of the external lymph-glands, and under these circumstances may be mistaken for tubercular or syphilitic lymphadenitis. The diagnosis is perfectly simple provided we do not forget the blood-examination or exclude leukemia because of the slight enlargement of the glands. This mistake is especially apt to occur with the gastro-intestinal form of leukemia, in which the only external glandular enlargement is in the neck.

Pseudoleukemia, or Hodgkin's Disease.—The post-mortem appearances are in all respects identical with those of leukemia, and the two diseases differ only in the blood-condition. Hodgkin's disease shows *normal blood* during the greater part of its course. Toward the end a slight leukocytosis may appear, but there is never the slightest resemblance to leukemic blood. The reported transitions from the one disease to the other are probably mythical. Hodgkin's disease is usually known to surgeons as lymphoma, lymphadenoma, lymphosarcoma, or malignant lymphoma. The confusion of terms is unavoidable, since there appear to be no reliable differentiæ, either gross or microscopic, between sarcoma of the lymph-glands, lymphoma, and Hodgkin's disease. The surgeon's chief interest in such cases is in distinguishing Hodgkin's disease from leukemia, and this he can very easily do from the blood-examination.

The more rapid the advance of the disease the more likely is it that the polynuclear leukocytes will be somewhat increased. Most cases run a long course—five to ten years—and in such the blood remains normal till near the end. On the other hand, I recently watched a case which ran its entire course in six weeks, and in which there was always some polynuclear leukocytosis.

Bacteriology of the Blood in Pyemia and Septicemia.—In a certain proportion of severe septic cases, such as those following wound infection and puerperal cases, the bacteriological examination of a syringeful of blood taken from a vein at the bend of the elbow gives some information as to diagnosis, prognosis, and treatment. Not all cases, however, even of the severest type, show any bacteria in the peripheral circulation.

The blood may be taken with any ordinary hypodermic syringe.

This is sterilized by heat. The bend of the elbow is rendered aseptic as if for operation, and all traces of the antiseptics used washed off with boiled water. Pressure above the elbow makes the veins stand out, and into any one of them the needle of the syringe may be plunged directly without any preliminary dissection. The piston is then withdrawn until the barrel of the syringe is filled. After pulling out the needle moderate pressure prevents all hemorrhage, and within an hour or two there is no discomfort left. The pain caused is hardly greater than that of an ordinary hypodermic injection.

Blood so collected is poured over the surface of 2 or 3 blood-serum "slants" and cultivated in the thermostat.

The presence of the streptococcus or the golden staphylococcus is almost always equivalent to a fatal prognosis. The presence of the Staphylococcus albus is of slight importance, being usually due to contamination.

The presence of the streptococcus may be an indication for a trial of the antistreptococcus serum.

Aseptic Post-operative Fever.—In a certain number of cases, after operations in which the wound is closed without drainage, a certain amount of fever is present for a few days, even where the wound eventually heals by first intention. Such cases are accompanied by moderate leukocytosis, and the presence of such an increase after operation cannot afford any presumption that the wound will "go septic." Presumably there are bacteria in every healing wound, even in those that heal by first intention, and the presence of these organisms, together with the setting free of nuclein from the cells destroyed at the operation and in the healing process, is sufficient to account for the leukocytosis.

Fractures.—The majority of simple fractures do not affect the blood, but in a certain number of cases they are followed by leukocytosis. In two of these cases I have known thrombosis to follow. Whether this was a mere coincidence or whether thrombosis is really more likely to occur in cases where leukocytosis is present, I cannot say.

Lymph-scrotum and Chyluria.—The presence in the blood of the embryo of the Filaria sanguinis hominis, while often unattended with any symptoms or signs, may be associated with a chylous urine, a chylous hydrocele, or elephantiasis of one region or another. These conditions are caused by the presence of the adult filaria in the lymph-vessels. It seems to have a special fondness for the lymphatics of the urogenital tract. The wall of the lymphatic is inflamed and the lymph-flow is obstructed.

The embryo filaria is usually present in large numbers in the general circulation, and can be seen in fresh slide-and-cover-glass specimens. Its presence is first noticed by the disturbance among the neighboring corpuscles, which are knocked about by the lashing of the filaria's tail. It is apt to be present in the peripheral circulation only at night, so that this time should be selected for the examination. The embryo worm is about 40μ in length and about 5 to 10μ in diameter, with a blunt head and a pointed tail, the whole organism being enclosed in a translucent sheath which can be seen projecting

beyond the extremities of the body. The organism is easily stained with fuchsin and other ordinary stains.

Not all cases of chyluria, lymph-scrotum, or elephantiasis are due to this worm, for the lymphatics may be blocked by other causes. But every case should be examined for the filaria, and in the majority of cases it will be found.

Hemophilia.—A tendency to bleeding from any surface of the body, occurring either spontaneously or from slight trauma, such as a scratch or bruise.

Etiology.—The disease is at least twelve times more frequent in males than in females, and where it occurs in females it is usually of a mild type. It is almost always hereditary, but the mode of transmission is remarkable in that it is *through* the females, but *to* the males, as a rule.

Though the disease may show itself from the time of birth, it is usually not until the first few years of life are past that it shows itself. It is especially apt to cause trouble during dentition and at puberty, but 70 per cent. of the cases appear before the fifth year. It rarely begins in adult life. The actual cause of the disease is unknown.

Symptoms.—In the severest cases hemorrhages occur spontaneously or from the slightest trauma. They may be confined to the skin or to the mucous surfaces, or may extend to the serous surfaces. Occasionally blood is poured out in the interior of various organs. Spontaneous hemorrhage is especially apt to occur in the scalp or the genital region (Treves). The oozing may cease within a few minutes spontaneously or under treatment, or it may go on for days or even weeks. When the hemorrhage can be checked it is well borne, and the restitution occurs quickly; but the pulling of teeth, circumcision, or even a slight scratch may occasion a fatal hemorrhage.

Hemorrhage may take place into joints, and be attended with pain, swelling, and fever. No characteristic changes are found in the blood. The anemia is like that seen after any other hemorrhage.

Prognosis.—Some cases are fatal within twenty-four hours. The tendency may disappear in adult life if the patient can be piloted safely through childhood. Death may occur either from hemorrhage or from some intercurrent infection, to which such patients are naturally very liable.

Treatment.—Prophylaxis is of the first importance. The child should be carefully guarded from scratches, cuts, and bruises, no teeth should be extracted, and every possible occasion for bleeding avoided. Should hemorrhage occur, gauze soaked in perchlorid of iron should be applied, and firm pressure exerted and continued as long as is necessary. The internal administration of such drugs as ergot, gallic acid, and lead acetate is probably useless. The anemia should be combated in the ordinary manner and the general health carefully attended to.

CHAPTER V.

WOUNDS AND CONTUSIONS; BURNS AND SCALDS; EFFECTS OF LIGHTNING; SHOCK; FAT-EMBOLISM; REPAIR OF SPECIAL TISSUES.

WOUNDS.

Definition.—A wound is the forced separation of any portion of the skin or mucous membrane in which the protecting covering of the underlying tissues is destroyed and the latter exposed to the influence of the air and other extraneous matters.

Classification and Mechanism.—Wounds of the surface involving exposure of the subcutaneous connective tissue are divided, according to the conditions of their edges, into the following:

1. Those with well-defined and sharp edges. These are subdivided into *incised* and *punctured* wounds.

2. Lacerated solutions of continuity of the surface. These are known as *lacerated wounds.* They occur when there is excessive tension upon the skin by the application of a dragging force, or where the tissues are forced against some underlying hard or unyielding part, as, for instance, the skull.

3. Contused breaches of tissue. These are known as *contused wounds.* They are caused by an object with a broad surface coming in contact with a portion of the body, or by falls upon hard irregular surfaces. Wounds following the blow of a club, or the entrance of some missile into the body, as, for instance, those from firearms (gunshot wounds), are familiar examples of contused wounds.

Other classifications include *penetrating wounds*, which are caused by a foreign body entering a cavity of the body without emerging, and *perforating wounds*, in which, having penetrated a portion of the body, it again emerges. When some specific poison has entered the wound at the time of its infliction, it is spoken of as a *poisoned wound.* When wounds have been infected with those organisms which excite putrefaction and disorganization of tissue, they are said to be *septic* wounds. In the absence of such infection the wound is said to be *aseptic.* More or less destruction of tissue characterizes all wounds.

Symptoms.—The three cardinal symptoms of a wound are (1) separation and gaping of its edges; (2) hemorrhage; (3) pain.

Separation and Gaping of the Wound-edges.—This results from the presence of elastic fibers in the connective tissue and cutis. It emphasizes the elasticity characteristic of the uninjured skin. The degree of the separation of the wound-edges depends upon the number and direction of the elastic fibers and, in addition, upon the depth of the wound itself and its direction. If the latter be parallel to that of the

elastic fibers of the skin and connective tissue the separation will be comparatively slight. Upon the other hand, if the elastic fibers are separated in a transverse direction the separation will be greater. Wounds with considerable depth gape more than those that are merely superficial.

Hemorrhage.—The hemorrhage which ensues upon the infliction of a wound depends upon the size and condition of the divided blood-vessels, as well as upon the depth, length, and breadth of the wound. This symptom varies greatly in different wounds of the same variety, as well as in different kinds of wounds. As a rule, it is less marked in contused and lacerated wounds than in those with clean-cut and sharply defined edges.

Pain.—Pain is the usual immediate accompaniment of a wound, and results from the coincident injury and subsequent irritation of sensory nerve-fibers in the injured tissues. Its character is usually described as "sharp" or "burning." It is felt in the area of distribution of the nerve or along the trunk of the latter. The pain varies, also, with the mechanism of the production of the wound. If the nerve-fibers are rapidly and thoroughly divided, the pain, as a rule, is less. The wound may be inflicted so suddenly and rapidly that no pain whatever is experienced. Mental excitement at the time of the injury likewise lessens the pain. The pain may also vary with the variety of wound inflicted. In clean incised wounds the wounded person may not be aware that he is injured until his attention is attracted to the wounded part by the presence of blood. Contused wounds are the most painful of injuries. Certain conditions of temperament exert restraining influences upon sensory nerves and the cortical centers. For instance, courageous persons and those in a furious rage, on the one hand, and those who exercise a quiet self-control, on the other, suffer least from the pain of an injury.

Clinical Course.—Wounds in which the edges are sharply defined and but slightly separated may heal in a comparatively short time without any essential change being observed in their surroundings. The interspace is filled by a very narrow coagulum which causes agglutination of the wound-edges. The upper layer of the coagulum projects just beyond the edges; this becomes dried and forms a thin linear scab. This scab exercises a hermetically sealing effect upon the wound. Very slight violence may reopen the wound in the earlier stage of this reparative process. As organization takes place in the thin cement of blood-clot, the union of the wound-edges through the medium of this becomes more firm, until the thin and narrow surface-scab falls off, leaving a dark-blue groove covered with epidermis in the process of formation. This is called the *cicatrix*. Other things being equal, the rapidity of this healing process is directly proportional to the degree of separation of the edges of the original wound. For instance, small and incised, as well as some punctured wounds which have not been exposed to septic or other irritating or disturbing influences, may heal in the course of twenty-four hours. In general, however, from five to seven days are required before the completion of the healing process, as announced by the falling off of the scab, occurs.

Similarly, in the skin very considerable losses of substance, particu-

larly if these extend only to the rete Malpighii, may undergo complete repair in a very short time. Here the hemorrhage being very slight, rapid drying of the effused blood takes place, and under the protection of the crust thus formed complete cicatrization soon follows. Very different, however, is the process in a widely gaping wound if nature is left unaided or disturbing influences enter. Rapid drying is prevented by the extent of the injury and the size of the coagulum as well as by the presence of a large quantity of lymph which ooze from the spaces which have been opened. Here the conditions favorable for the implantation and reproduction of septic organisms are present. These include, first, the presence of organic tissues deprived of their protecting cuticle and with their vital resistance otherwise lessened by the infliction of an injury; second, a favorable temperature (blood-heat); and third, moisture. With the rapid drying of the surface of the coagulum in trivial incised wounds the septic organisms are deprived of that moisture which is essential to their proliferation. In the case of large gaping wounds, however, this desiccation cannot take place readily, invading micro-organisms rapidly multiply under the favorable conditions present, and as a result putrefaction and disorganization of tissue take the place of repair. In the course of twenty-four hours the wound-surfaces become covered with a semi-liquid and foul-smelling layer of broken-down tissue swarming with the bacteria of putrefaction. Following this, striking and peculiar changes take place in the neighborhood of the wound, due to the spread of infection from the original site of proliferation of the bacteria. These changes are characterized by a more or less broad zone of redness which makes its appearance about the wound-edges together with increased heat in the part and, finally, by increased density, or induration of the surrounding tissues. At the same time the patient complains of pain and a feeling of tension in the parts involved in these nutritive disturbances. With progressive putrefaction of the coagulum these symptoms increase. Where the surrounding parts have been involved in the original injury, as in contused wounds, a foul-smelling semi-fluid mass issues from beneath the wound-edges, mingled with the débris of broken-down tissue. If improvement takes place a yellowish-white secretion, not unlike cream, makes its appearance upon the edges of the wound and in its depths. This is the "laudable pus" of the old surgeons, and makes its appearance about the fifth day. Under favorable conditions and with the measurable return of the quality of vital resistance to the involved tissues the ichorous discharge ceases, and the wound enters upon the stage of suppuration.

In the stage of suppuration the classical symptoms of an inflammatory process—namely, redness, heat, pain, and swelling—diminish. The time covered by this stage of the process of healing will vary with the depth of the wound, the extent of laceration of its edges and contusion of the neighboring tissues. In an average case of lacerated wound, from about the seventh day a mass of material of a pinkish hue forms beneath the layer of pus and is observed to rise from the depth of the wound. This mass, which is made up of small papillæ, continues to rise until it fills in the entire wound-cavity. Its surface presents a granular appearance, the papillæ are called *granulations*

and the wound is said to have entered upon the *stage of granulation* (Fig. 30).

The surrounding parts at this time begin to assume their normal condition. With the disappearance of redness and heat, tenderness together with some slight degree of induration alone remains. The persistence of these latter indicates that the reparative process is still going on in the depths of the wound. In the beginning of the granulating stage of the healing process the granulations become more or less easily injured and bleed upon the slightest touch. As the body of the wound becomes filled with granulation-tissue the latter becomes, to some extent, solidified, loses its bright-pink color, and becomes pale. Coincidently with these changes a shrinking process goes on, with corresponding diminution of the cavity of the wound.

FIG. 29.—Abdominal wound: healing by first intention, tenth day.

Finally, when the granulating surface reaches the level of the surrounding skin, a narrow strip of new epidermis begins to grow around the wound-edges. This slowly increases from without inward. One concentrically growing zone after another is added to the new tissue until, these meeting in the middle, the granulating surface is completely covered, and cicatrization is accomplished.

The processes described are what are known as healing by *primary* (Fig. 29) and *secondary* intention. Healing by first intention seems almost a physiological process; it is the simplest and most direct method of repairing lost tissue, and is quite similar to, if not identical with, normal epithelial metamorphosis. In the second method of repair, or healing by second intention, tissue-reproduction attended with suppuration is marked by the presence of inflammatory conditions with their essential and characteristic symptoms, known since the days of Galen as *redness* (*rubor*), *local heat* (*calor*), *swelling* (*tumor*), and *pain* (*dolor*).

Histological Considerations.—It was formerly supposed that the coagulum formed in the interspace served the purpose of accomplishing immediate union of the wound, when this took place. It is

now known, however, that direct adhesion of the histological elemen of the parts and, hence, immediate union do not occur without furth effort. A fine network made up by trabeculæ is formed in the exude fibrin, from which processes pass into the open blood-vessels and in the clefts or spaces in the tissues.

Blood-corpuscles and small portions of necrotic tissue and coag lated fibrin are formed in the cavity of the wound itself. Some of t blood-corpuscles have assumed a star-shaped appearance, while othe are simply swollen and pale in color. Coagulation in the neighbori

FIG. 30.—Granulating wound on the surface of a nodule.

capillaries follows the passage of the trabeculæ into the mouths of open blood-vessels. The last traces of the red blood-corpuscles h almost entirely disappeared at the end of forty-eight hours, their forr site being marked by spaces in the network. Those which rem become either translucent or finely granular.

With the disappearance of the red blood-corpuscles the so-cal cells of new formation make their appearance. These are small rou cells with a clear nucleus, and resemble the young cells of connect tissue as well as the colorless blood-corpuscles. These fill up the and are crowded into the surrounding injured structures and neighb ing perivascular spaces. About the fourth day blood-vessels pass small loops from the edges of the wound and meet and unite in middle of the intervening coagulum (Julian Arnold). These ves spring from the capillaries by a process of "budding," a slight gra lar thickening (protoplasmic proliferation) marking the site upon wall of a capillary where a new vessel is about to bud. This gran thickening or projection develops into a fine cord with a thread- termination. The base of this protoplasmic cord becomes hollo out upon the side toward the vessel from which it springs, and bl enters the cone-shaped base from the parent vessel. Arch-sha connection between two capillaries is established by union of th protoplasmic cords, and the protoplasmic arch is thus formed. Fina complete communication is established by a process of canalizat

which takes place in the intermediate portion of the arch. The protoplasmic arches become lined with endothelium.

By a process of cleavage new cellular elements develop, new capillary vessels are formed, and this primary cellular layer is enlarged from within by the adjacent round cells of new-formation, which form the adventitia of the new vessels. These formative round cells of Marchand fill the wound and soon begin to undergo transformation. A framework springs up in the spaces between the cells, which, in all probability, originates in the cells themselves. This framework is partly striped and partly granular at first, but later in the development the striped appearance becomes more clearly defined, and there eventually develop in the intercellular substance fine fibers at the site of the former striations. Between these fine fibers are found spindle-cells, which by some are supposed to be the remains of the formerly existing mass of round cells. The new tissue now closely resembles young connective tissue; it is richer in blood-vessels, however. The spindle-cells, as well as the round or formative cells, disappear by processes of granular degeneration and absorption, or they are either taken up by the circulation when only partly developed or destroyed by cell-action.

Finally, the process of repair is completed by the sheltering cover of the epidermis. Pending the formation of the latter, a crust of broken-down blood-corpuscles and epithelial scales, held together by dried exudation, forms. Beneath this temporary protection new epithelium, furnished by the rete Malpighii of the adjoining skin, develops. Nuclear segmentation of the cells of the latter takes place, and these new cells arrange themselves from the periphery over the surface of the new-formation until they meet in the center, and the surface of the wound is finally covered in.

The histological processes followed in the healing of a wound by second intention, or healing by suppuration, are essentially the same. When the round cells appear and are brought in contact with the putrid blood, they rapidly perish and are cast off with the secretions of the wound. The latter consist, at this time (during the first three days), of portions of fibrin, red blood-corpuscles in different stages of decomposition, granular detritus, bacteria, and dead connective-tissue cells. These cells are undergoing changes in quality and form, and constitute with the leukocytes which migrate to the parts the principal components of pus. While numerous connective-tissue cells are being thrown off from the surface of the wound, new ones are being supplied to take their place, until the lowest layer, becoming gradually supplied with blood-vessels, remains to form the young connective tissue, which latter, with its numerous loops of vessels, each surrounded by a growth of the same connective-tissue cells, appears as a collection of bright and irregular nodules, the granulations. With lessened discharge of pus the granulation-tissue gradually fills up the cavity, and the size of the latter is diminished by a general shrinkage of the whole wall. Finally, as the surface of the wound becomes level with the surrounding surface, cicatrization is completed by the renewal of the protective epidermis. While, as a rule, the new epidermis forms a narrow zone about the edges of the wound, it occasionally happens, in addition, that little islets spring up away from the margin, themselves to become the cen-

ters of successive zones of new epidermis. Inasmuch as these cann spring from the rete Malpighii, the explanation of their occurrence that they either originate from the cells surrounding the sweat-glan and hair-follicles which may have escaped injury, or are the offsprin of epithelial cellular elements that have been accidentally engraft upon the granulating surfaces during changes of dressings, or in son other way. In any event, it is not probable that these epithelial cel are formed from the round cells of the granulating tissue.

The question of the origin of the connective-tissue cells during the healing process h received a great deal of attention. It was formerly supposed that the spindle-shaped c puscles, the only cells then known to exist as connective-tissue cells, were the progenit of the round cells. The origin of this belief was probably the observation previously ma that in fetal connective tissue, spindle-cells developed from the round cells are found lyi in numbers in the matrix (Virchow). Recklinghausen in 1863, in the course of experime on the cornea of rabbits and frogs, found in addition to the so-called fixed corneal corpusc small round cells which possessed the peculiar property of changing their form and positi in a manner entirely independent of each other. They bore a striking resemblance to pus-cells as well as the white blood-corpuscles. This aroused inquiry which finally resul in Cohnheim's successful demonstration of the direct origin of the migratory cells from blood and the identification of these with the white blood-corpuscles (1867), although long ago as 1824 Dubachet in France, and again in 1846 Waller in England, discovered emigration of the white blood-corpuscles through the walls of the vessels in the mesent of the frog without, however, realizing the importance of the subject. Whether all the present in a case of prolonged suppuration can be accounted for by Cohnheim's theory is interesting question. It is difficult to understand how the blood could furnish such enorm quantities of colorless blood-corpuscles. According to the Cohnheim diapedesis theory, only must the blood furnish the enormous amount of pus through its white blood-corpuscl but in addition the round cells, the newly formed blood-vessels, their walls (first homo neous and then nucleated), the young connective tissue, and finally the granulation-structu must be accounted for. In opposition to this the adversaries of the exclusive diaped theory, notably Recklinghausen and Stricker, reported a series of observations wherei was sought to show that connective-tissue corpuscles, as well as endothelial cells, underg contractile change of shape and division. This was combated by Cohnheim and his foll ers by means of the classical experiments with cinnabar. In order to distinguish the wl blood-corpuscles from other cell-elements for which they might be mistaken, the blood frogs was injected with cinnabar, the finely divided particles of which were absorbed the white blood-corpuscles. The frogs were then subjected to an injury, at the site which the white blood-corpuscles could be seen escaping, enclosing the particles of cinnab This was met by Recklinghausen by calling attention to the well-known fact that the pa cles of cinnabar may escape directly into the tissues from the blood-vessels of frogs injected, and there stain cells formed outside the vessels. At the present time, howe the theory of extravascular formation of cells, although it constitutes the most rational planation of the reparative and regenerative processes which take place after destruction parts, has not been established by direct observation. On the other hand, it may be that, while the theory of migration of the colorless blood-corpuscles appears to be est lished, the proof that these take an active part in the restoration of lost parts is wanti The controversy as to the formation of the cicatrix through the medium of the round ce whatever the origin of the latter, cannot in all probability be settled until means of dis guishing between young connective cells and colorless blood-corpuscles have been covered.

The distinction between healing with and without inflammation, heretofore made, must be abandoned. Furthermore, Galen's definiti of the conditions present must be broadened. Experimental resea on animals and observations in man have thus far determined that t local disturbances following an injury to the tissues are essentia those of the inflammatory process, including as they do, (1) dilatati of blood-vessels; (2) increase in the permeability of their walls; augmented supply of nutriment to the tissues; (4) migration of wh blood-corpuscles through the vascular walls into the surrounding co nective-tissue spaces. In an advanced stage of the process th

probably occurs (5) proliferation of pre-existing cells; and under certain circumstances there occur (6) processes of degeneration and decomposition, resulting in more or less loss of tissue.

The Treatment of Wounds and Contusions.—In the formal consideration of the subject of the treatment of wounds and contusions, following the division of the subject already laid down, it will be convenient to deal, first, with injuries which involve a breach of continuity of the surface, whether of skin or mucous membrane, and to which the general term "wound" is applied, and secondly, with subcutaneous injuries.

The underlying principle to be observed in the treatment of all cases of injury may be summed in the word "rest." If the patient escapes immediate death there is reason to hope that the natural processes of tissue-building embraced in the term "repair" will be sufficient, providing these are permitted to go on in an uninterrupted manner, to restore the patient to comparative or even perfect health. In addition to this, arrest of hemorrhage in wounds, and in some instances of subcutaneous and internal injuries as well, will be demanded.

The methods of securing the most perfect rest of the injured parts will vary with the character of the injury, the special qualities of the tissues involved, the location and conformation of the injured parts, natural tendencies to displacement of separated structures, etc. These matters will be more fully discussed in the chapters devoted to the surgery of separate regions. In the present connection the subject of the general principles involved in the treatment of injuries to individual structures will alone be considered.

Arrest of Hemorrhage.—Complete hemostasis is to be obtained in every wound. To this rule there is but one exception—namely, a wound in which the defect caused by loss of tissue is to be filled by an attempt at so-called organization of a blood-clot. In small wounds and in those in which only the smallest vessels are divided, as well as in wounds involving cartilaginous and fibrous structures, hemostasis may be *spontaneous.* In slightly larger wounds bleeding may be arrested by mere exposure to the air. The majority of wounds coming under the care of the surgeon require artificial methods of hemostasis. All of these, as well as the natural means employed, act, when efficient, by producing a mechanical obstruction to the flow of blood from the divided vessel, this obstruction lasting for a sufficient time to ensure permanent sealing of the divided vessel-end.

First among methods of arresting hemorrhage is *pressure.* This may be *digital*, the finger being placed upon the bleeding point, either distad or proximad to the same. This, as a rule, is a temporary expedient only, and when placed upon the cut end of the bleeding vessel the finger in the wound is in the way of the manipulation necessary in subsequent treatment. It is objectionable also in other respects—*i. e.*, it increases the risks of suppuration by favoring the introduction of septic material into the depths of the wound, as well as by producing increased traumatism of the parts involved in the injury, and thus emphasizing the *locus minoris resistentiæ*. Hence digital compression is to be classed as a temporary expedient, to be used only in cases in

which an unnecessarily large amount of blood will be lost before othe and better methods can be applied. As an example of such case may be mentioned extensive wounds of the forearm involving th radial and ulnar arteries, when pressure of the brachial will arrest th hemorrhage; or again in operations upon the kidney in which th renal artery and vein have been wounded with the organ still *in siti* and in which it would be unwise to attempt to employ a forceps a once, when a thumb and finger introduced into the depths of th wound will so much more readily and quickly grasp the pedicle an arrest the hemorrhage, and will serve also as a guide for the applica tion of the forceps.

Compression by means of *sponges* or *compresses* is far superior t the digital method, as the pressure may be exerted over large or sma areas at will and, besides, is more even, thus interfering less with tl local nutrition of the part than digital pressure. This means of hem stasis is particularly applicable to wounds involving large areas (wounded arterioles and venules. *Heat* is advantageously used connection with gauze compresses. This may be dry heat, appli through the medium of towels direct from the sterilizer and laid up the wound-surface either with or without compression, and of a te perature almost unbearable to the operator's hand. The hot gauze towel should be covered with other towels, so that the effect may continued as long as possible without the necessity of renewal. Ju previous to the application the wound-surfaces should be carefu dried. This application of heat likewise serves to counteract whate shock is present. One towel or a succession of towels may be us *Moist heat* may be applied by means of towels wrung out of ve hot plain water or a 0.6 per cent. salt-solution in the case of no infected wounds, or some antiseptic solution in the case of wour suspected of sepsis. *Cold*, on the other hand, while a useful hen static agent under some circumstances, is not to be used directly a wound-surface, for the reason that it devitalizes the tissues to great an extent.

Of *chemical means* for the arrest of hemorrhage in the treatm of wounds, the less said the better. They have no place in the arr mentarium of the well-equipped surgeon. They do more harm tl good, and, whether the wound be non-infected or septic, chemi agents in wound-treatment for the arrest of hemorrhage are ab lutely and unreservedly contraindicated. Even should they acc plish their object, they do this by an unnecessary destruction of tis thus increasing the wound-area; they lead to increased exudation, p dispose to secondary hemorrhage, inflict unnecessary traumatism u adjacent structures, still further lowering the vital resistance and r dering impossible primary union or any approach to it, and in ev way delay rapid healing. They are inefficient in the face of ac hemorrhage, and in wounds the bleeding from which is of a mi character, other and better means are always within reach.

Last but best of the many means at our disposal in the arres hemorrhage from wound-surfaces is the application of the *hemost forceps.* It accomplishes the end either by pressure alone or by pr ure combined with torsion. Should this means prove unsuccessful,

application of the ligature is at once efficient and trustworthy. The degree of traumatism inflicted is slight if the proper instrument and approved method of application are employed; the result is immediate and satisfactory.

Cleansing and Disinfection.—Preliminary cleansing of the wound and its surroundings constitutes the difference between operative and accidental wound-treatment. It is the lack of this that renders the latter difficult of management. The treatment of all non-operative wounds is essentially the same, the object being to cleanse thoroughly, first the surroundings, and second the wound itself, so that the latter will conform as nearly as possible to a properly treated operation-wound. While aseptic wound-treatment is mainly applicable to wounds made by the surgeon, the latter will occasionally be summoned sufficiently early to an accidentally inflicted wound or to those made under circumstances which impel him to consider the wound not materially infected, in which case the aseptic treatment may be instituted. In any event methods must be employed which will, as far as possible, sterilize the site of the wound, its immediate neighborhood, and all articles that are likely to come in contact with it, including the hands and persons of the surgeon and his assistants. A large proportion of the pathogenic bacteria which finally find their way into wounds have their habitat upon the cutaneous surface of the body or in those articles of wearing apparel worn next to the skin. Others less virulent, but capable of becoming actively pathogenic under conditions of lessened local vital resistance, such as the *Staphylococcus epidermidis albus* (Welch), are also present, as well as others that are positively harmless. Only criminal carelessness will permit a surgeon to make an incision into integument which has not been deprived, as far as possible, of these lurking sources of danger. No disinfection or sterilization of instruments, care in operative technic, nor application of antiseptic dressings can in any degree compensate for failure in this respect. (For aseptic operative technic see Chapter XI.)

In accidentally inflicted wounds the indications for preventing further infection are as imperative in their demands as are those precautions taken prior to the infliction of an operative wound. The clothing must be removed and the surface of the body in the neighborhood subjected to a vigorous scrubbing with warm water and a strongly alkaline soap, a clean bristle hand-brush being employed for the purpose. The parts are then to be shaved, again scrubbed, washed with ether and alcohol, rinsed with a 1 : 1000 sublimate solution, and covered with a gauze compress wetted with the latter, pending further care of the wound, such as the introduction of sutures, etc. Further precautions against reinfection consist in covering the surrounding parts with sterilized towels.

In the case of wounds of cavities lined with mucous membrane, special cleansing methods are to be followed. The mouth and the pharyngeal cavities are cleansed with a 1 per cent. solution of potassium chlorate or a wine-colored solution of potassium permanganate. The teeth are to be vigorously brushed with a stiff tooth-brush. Carious teeth should be removed. The vagina should be cleansed with soap and warm water, a bunch of gauze or absorbent cotton grasped in a

sponge-holder or forceps being used to assist in the cleansing. I wounds involving the rectum the latter is to be emptied and irrigate and its upper part packed off with bunches of gauze coated with vas elin while the sutures are being applied. Threads are attached to th gauze to facilitate its removal. The bowels are confined for two c three days, and when finally moved the stools are rendered fluid b proper laxative medication and enemata to prevent separation of th suture-line.

In the treatment of accidental wounds the cleansing of the wour itself consists in the removal of all *foreign material*, the presence which must necessarily interfere with repair. Blood-clots are remove as well as all macroscopic dirt. Cases coming under the care of tl surgeon after necrotic changes have occurred demand the removal all dead or dying tissues, as far as possible. The removal of the latt unless demanded at once by grave general sepsis, may be left to n ture's efforts, but may be greatly facilitated by the employment of agent that shall combine antiseptic and stimulating properties, such naphthalin, the rapidly forming granulations tending to throw off t devitalized parts. Other foreign material, such as bits of glass, ste buttons, portions of clothing, small fragments of bone, etc., must removed by means of pieces of gauze, thumb-forceps, and irrigati Instruments especially designed for the purpose, such, for instance, bullet-forceps, are employed in suitable cases, and, in addition, the of the knife, scissors, and curet becomes necessary under certain cumstances. As a cutting instrument for enlarging wounds in order gain better access to foreign bodies, the knife is to be preferred to scissors, for the reason that the latter divides the structures witl crushing effect, and hence inflicts an additional degree of traumati The curet is mainly useful in the removal of septic granulation-tis in the course of the after-treatment. *Gunpowder grains* may be moved in great part by a vigorous scrubbing with a stiff brush un an anesthetic and subsequent removal of the remaining grains b fine-pointed knife and delicate forceps. Even if each grain is not moved in this way in its entirety, it is broken up into fine particles wh finally disappear in the majority of cases, leaving but little staining the tissues.

Contused Wounds.—It is always to be borne in mind that r union and good functional result are to be desired in all wounds h ever contused or lacerated, and to this end every other considera is to be subservient. In former times it was considered useless to tempt to obtain primary union in cases where the wound-edges contused. The existence of this condition, indeed, was considere contraindication to the closure of the wound, violent phlegmo inflammatory action frequently ensuing. The reasons for the occurr of the latter are now well known. What with the introductio irritating micro-organisms at the time of the reception of the inj the lessening of the vital resistance of the involved tissues by the la and, in addition, the possibilities of further infection through the dium of the suture-material or other means employed to close wound, in the light of our present knowledge the only wonder is the patients escaped with their lives, not that their wounds sh

have healed. Immediate union of wounds with contused edges is now attempted under circumstances where the requirements of a rigid asepsis and antisepsis are met. Cases will arise, however, in which the tissues are crushed beyond hope of recovery. Here either the attempt to obtain primary union must be abandoned, or the crushed portions must first be removed.

Coaptation.—This consists in replacing the severed tissues in as nearly their normal relation as possible. This is easily accomplished in the case of incised wounds, but in contused and lacerated wounds it is difficult, and when there is considerable loss of tissue, impossible. It should be attempted in all wounds that will permit it. It may be *immediate*, or directly following proper hemostasis and cleansing and disinfection, or *secondary*, some hours or even days intervening, as in cases in which, from the nature of the wound, a copious discharge is expected to occur. *Position* ranks first in securing coaptation. The wounded part is to be brought into such a position as to diminish to the greatest possible extent the tendency of its edges to gape. This may be attained by either flexing or extending the parts, according to circumstances. Bandages, fixed dressings such as those of plaster of Paris, and splints of various kinds are used to insure maintenance of the proper position. *Pressure* may be employed in suitable cases, as in small wounds whose edges show very slight tendency to gape, or indirect by means of rolls of gauze placed on each side of the wound and held in place by a retaining dressing. *Adhesive material* is sometimes used, such as adhesive plaster, collodion, plain or incorporated in gauze or absorbent cotton. It is only in small or superficial wounds that adhesive material is of service, and then only when asepsis is reasonably well assured. In large wounds it is used as an adjunct to other measures. Collodion is particularly useful in drawing together the suture-line, while adhesive plaster is useful applied outside the dressing as an adjunct to the binder or bandage, especially in such parts as the chest or abdomen, where absolute rest is most essential and at the same time difficult to obtain.

Sutures rank next in importance to position and rest in maintaining the parts in their relation to each other. The strength and durability of the material employed will depend upon the character of the tissues to be approximated, their situation, etc. In suturing the integumentary tissues the materials selected should be such as are least favorable to germ-growth. For this reason catgut should be discarded, and silkworm-gut, silver wire, or silk used. For those deeper structures which take long in healing, such as bone, tendon, and fascial and aponeurotic tissues, stouter and more resistant material will be required than in the case of muscles, nerves, and blood-vessels, which unite more rapidly. According to J. B. Murphy, however, silk is the preferable material in suturing wounds of blood-vessels. The traumatism inflicted by the sutures themselves should be borne in mind, and the size and character of the material should be selected with this in view. Severed nerves, muscles, tendons, bones, fasciæ and aponeuroses, and the larger blood-vessels should be approximated each with its appropriate suture. In superficial wounds imperatively requiring suturing, such, for instance, as those located over the point of the elbow, the knee, and of the scalp,

and which tend to gape widely, skin-sutures alone are sufficient. deeper wounds sutures may approximate the wound-layers separate or all may be included in one layer, these being either buried or movable. In bringing the sutures through the skin they may be ma to emerge near the wound-edges or at a distance from them. T latter are known as "relaxation-sutures," since they transfer the str of the stitches from the immediate neighborhood to a distance. *Tens* upon the wound-edges should be avoided whenever possible, since, a result of the traumatism, these possess a lower vitality than the pa at a distance, and hence are more liable to become infected. The t sion of the suture may be overcome in great measure by correct po tion and relaxation-sutures; that arising from compression, if it res in necrosis of tissue, is inexcusable. In addition to necrosis and inf tion following the improper application of sutures, the strain pla upon structures sutured, particularly in the case of large defects tissues naturally unyielding, may be excessive in spite of every c upon the part of the surgeon. It may even prove to be more than structures can bear, in which case a cutting through of the tissues fr ulcerative action occurs. The tissues drag against the rigid and yielding thread, separation occurs in the suture-line, and the thr often becomes buried out of sight. This last effect sometimes res from undue swelling of the skin itself on account of infection from great tension upon the sutures, the result of overanxiety on the p of the surgeon to secure firm approximation of the wound-edges. this connection it should be borne in mind that all the purposes coaptation are fulfilled by a loose adjustment of the cut edges to e other. The attempt to do more than this and to force the inju parts firmly against each other will accomplish no more than sim approximation, and is fraught with risk.

Drainage.—By drainage is meant the process of removal of wound-secretions. Every wound, however small, is the seat of a tain amount of exudation. In the early stages this is serious, bu the event of infection it becomes seropurulent and finally purul The indications for drainage vary in different wounds, and the meth of drainage to be employed are governed by the character of the charge. Small incised wounds require no artificial drainage; if c they may be closed, and if septic they may be left open for nat drainage. Large incised wounds of accidental origin, if tre promptly, may frequently be closed without drainage. If the de fascial and aponeurotic structures have been opened up, and ther invasion of muscular planes, and particularly if entrance into jo has been effected, artificial drainage must be provided for. Wo not necessarily extensive in themselves, but complicated by injurie the surrounding soft parts and likely to give rise to a large serous dation, may be left entirely open for the first twenty-four or forty-e hours and lightly tamponed with sterile or antiseptic gauze. *Secon suturing* may be practised in these cases. If decided infection taken place the secondary suture must be postponed until all trace this have subsided; otherwise, sutures having been introduced and loose at the time of the first dressing, the wound may be closed. method of primary drainage and secondary suture has much to rec

mend it in large non-operative wounds. In this manner speedy union may be secured in wounds in which, if sutured primarily, tissue-necrosis would have ensued as a result of pressure on the tissues by the suture, the cause of the pressure being the retention of the wound-discharges. Large incised wounds without coincident damage to surrounding tissues, even though sufficient time has elapsed and the surroundings are such as to excite a reasonable suspicion of the supervention of sepsis, may often be partially closed by sutures, the most dependent portion being left open for natural drainage, or artificial drainage being provided for. All lacerated and contused wounds must be drained except in cases where the contused and lacerated portions can be removed and the wound converted into a simple incised wound. This should be done whenever possible; but where it cannot be accomplished without impairment of function or too great loss of tissue, it is contraindicated.

All wounds of non-operative origin must be carefully watched. This applies with special emphasis to those that have been closed primarily; these are to be opened up freely upon the first evidence of sepsis. The border line between aseptic and septic wounds, or those likely to become so, is difficult at times to determine in the class under discussion, and the conservative surgeon will take the safe side in case of doubt. Given a wound upon a portion of the body, particularly where disfigurement is to be avoided, as in the case of the face, if the circulatory conditions favor rapid healing in spite of some exposure to infection, if the wound has been seen early and the most scrupulous precaution taken to remove any possible source of infection from the wound and its neighborhood, and if the circumstances surrounding the infliction of the wound in relation to sepsis do not contraindicate, then approximation of the edges should be accomplished at once. If, on the other hand, considerable time has elapsed since the infliction of the wound, the latter in the meantime having been exposed to conditions inviting sepsis, as contact with clothing or other probable sources of infection, if the surroundings do not admit of disinfection to the satisfaction of the surgeon, and if upon investigation the cause of the wound has been ascertained to involve septic conditions, drainage must be employed. In deep wounds with narrow external openings and in those involving joint- or other cavities, drainage is indicated. In large subcutaneous injuries, and in those in which decided losses of tissue cause so-called "dead spaces," counteropenings are indicated to allow of sufficient drainage.

Means of Drainage.—The simplest means of effecting drainage is leaving open the most dependent part of the wound, the so-called natural drainage. The most commonly employed means of artificial drainage is the use of sterile hygroscopic gauze or cheese-cloth material. It is indicated in wounds with serous or seropurulent discharge, the fluid being sufficiently thin to permit of its being acted upon by the capillarity of the threads of the gauze. In infected wounds the gauze may be impregnated with some antiseptic agent, such as iodoform or zinc oxid; in non-infected wounds plain dry sterile gauze will suffice. Silkworm-gut, horse-hair, spun glass, and narrow strips of oil-silk or rubber tissue, have been employed. They possess

some advantage in that they are easier of removal. A perforated covering of oil-silk or rubber tissue placed upon rolls of gauze or bundles of common lamp-wicking assists in the removal of the drains thus formed, the smooth exterior of the latter facilitating the withdrawal. This feature is a particularly desirable one in the removal of intraperitoneal drains.

In wounds from which the discharges are too profuse or too thick to be acted upon by capillary action, tube-drainage is employed. Tube-drains are made of rubber, glass, silver, and decalcified bone. The last-named material is absorbable. When non-absorbable tubes are employed they should be removed as soon as possible, since they ac as a foreign body to a greater extent than does simple gauze. Th latter should replace tube-drainage at the earliest possible moment Wounds are not infrequently maintained in a septic condition b the persistent employment of tube-drainage, for granulation-tissue o low vital resistance, and hence easy of infection, lines the fistulou track along which the tube lies. The fistulous tracks are some times difficult to heal, and it is only after the vigorous use of th sinus-curet to remove septic granulation-material that closure is finall accomplished.

Dressing of Wounds.—The protection of the line of coaptation of importance. The soft layers of cheese-cloth now so universall employed in the dressing of wounds are sufficiently non-irritating t be brought into direct contact with the line of union without harr Some surgeons prefer a narrow strip of Lister's oil-silk protectiv while others apply a layer of collodion in which iodoform or son other antiseptic substance has been dissolved. These are unnecessar save under the exceptional circumstances of wounds in localiti where it is almost impossible to keep the gauze dressings close applied to the wound and its surroundings. In view of the fact th any additional factor entering into the dressing material may introdu sources of sepsis, it should be accepted as a golden precept in the su gery of wounds that whatever is unnecessary may be mischievous a had better be omitted.

In addition to affording protection to the wound against infecti and injury, dressings are designed to absorb discharges escaping fr the wound. They are applied immediately following hemostasis, clea ing and disinfection, coaptation and drainage. The hygroscopic ga or cheese-cloth already mentioned serves the purpose admirably, an now almost universally employed. In case of non-infected wounds t gauze may be used plain; in infected wounds it must be impregna with some antiseptic substance. In cases of mild infection either io form or zinc oxid answers the purpose admirably; in most virul forms of infection some such decidedly germicidal agent as corros sublimate is employed. When there is a tendency of phlegmon inflammation to spread, saturating the dressings with a 2½ to 5 cent. carbolic-acid solution is of especial service. The original Li dressing, in which carbolic acid is held in the meshes of the gauze some resinous material, is now comparatively little used. In the p ence of evidences of infection, and particularly where sloughy tiss are to be separated, wet dressings of antiseptic and germicidal s

tions are indicated; otherwise, wounds heal more rapidly under dry dressings.

In order to afford sufficient protection to the wound the dressings should be applied with a generous hand, and should cover the parts for some distance from the wound itself. They should also be applied in such a manner as to offer the least discomfort to the patient and afford the greatest possible rest to the wounded parts. As an additional protection against infection from the atmospheric air, the gauze dressings are covered with a thick layer of common non-absorbent cotton sterilized by dry or steam heat. This is not the finely carded absorbent cotton of the dealers, which affords little or no protection against germ-invasion. Finally, the dressings are held in position by properly applied bandages (see Minor Surgery). Firm and equable compression, applied through the medium of large cushion-like dressings of gauze and cotton, affords considerable comfort to the patient, particularly when combined with proper position and complete muscular relaxation of the injured parts.

Revision of Dressings and Redressing of Wounds.—If with the occurrence of swelling the compression is increased to the extent of giving rise to pain in injured parts previously free from pain, or if from the restlessness of the patient or other circumstance the dressings become accidentally disturbed, *revision* of the dressings is demanded. That is to say, the bandages and dressing materials are to be rearranged, and perhaps the position of the injured parts altered. By the term *redressing* is meant the complete removal of one set of dressings and the application of another. The indications for the latter may be simply stated. If anything goes wrong in the neighborhood of the wound, as evidenced by heat, pain, or soiling of the dressings; or if the general well-being of the patient is disturbed by elevation of the body-temperature, headache, foul tongue, malaise, and restlessness, the wound should be suspected of being the cause. Under these circumstances the injured parts should be examined and redressed, such modifications of the dressings being instituted at this time as will meet the particular indications found to be present. Soiling of the dressings by a simple serosanguinolent discharge that has quickly dried in the meshes of the gauze does not of itself necessarily indicate exposure of the wound. If undue tension is present from failure of drainage, the drains should be cleaned; if the sutures are found to be cutting into the soft parts, these are to be removed in addition. If the line of approximation shows that infection has taken place, this should be met by appropriate means. If mild, as shown by slight reddening, wet antiseptic dressings may suffice. If a decided and extensive blush is present the sutures must be removed to give access to the wound-cavity, which must be thoroughly cleansed and loosely packed with iodoform gauze moistened with a 95 per cent. alcohol or a $2\frac{1}{2}$ per cent. carbolic-acid solution. The former has been found to be exceedingly useful in rapidly developed phlegmonous inflammation.

If no indication exists for the revision of a dressing or a redressing of the wound, it is a surgical error to disturb the dressings, save for the purpose of removal of drains, until the time arrives for the removal of the sutures—say a week or ten days. The technic

of redressings should be conducted with the same care as the original dressing.

Subcutaneous Injuries.—Injuries of this character involving an external wound have already been dwelt upon. In this connection it is intended to deal only with the parts which lie subjacent to the skin, and which present an unbroken surface—that is to say, contusions. For the detailed treatment of injuries to separate structures the reader is referred to the several chapters devoted to that subject.

The treatment of contusions will depend entirely upon the amount of damage inflicted. More or less pain is usually suffered in consequence of the involvement of sensory nerve-fibers in the traumatism, as well as from tension due to the presence of hemorrhagic and other effusions. For the relief of the pain due to the first-named cause the application of a lotion containing opium is useful. If this is combined with a $2\frac{1}{2}$ per cent. solution of carbolic acid in the proportion of an ounce of tincture of opium to a pint of the acid, the tendency to suppurative inflammation arising from infection of the devitalized structures through such channels as the hair-follicles will be combated, and the pain relieved as well. Care must be exercised in the use of both of these agents in very young children and old persons, for the reason that absorption takes place readily in the delicate integumentary structures of the former and the atrophied skin of the latter, and toxic symptoms may be produced. The old-time remedy known as the lead-and-opium lotion, consisting of a dram of lead acetate, an ounce of tincture of opium, and a pint of water, applied warm, is a grateful application in painful contusions. Rest and position, together with agreeable compression, are of service in relieving pain; at the same time they reduce swelling and tend to arrest further hemorrhage. Ho or cold water, the latter of ordinary room-temperature, or an evapora ting lotion of ammonium chlorid in alcohol and water, applied eithe warm or cold, as seems most acceptable to the patient, are to be men tioned. If necessary, an incision may be made, clots turned out, an bleeding vessels sought and secured. The readiness of tissues tha are the seats of a contusion to take on suppurative inflammation unde the influence of mildly infectious agents should be remembered, an strict precautionary measures should be taken accordingly.

If seen early, *massage* will be found to shorten materially the perio of disability due to the contusion. It is always indicated in those case in which there is no injury to important underlying structures and n infection. Massage may be employed later in the treatment and afte the subsidence of sensitiveness, for the purpose of hastening the ab sorption of effusions. This measure of treatment is particularly valuabl in subcutaneous injuries occurring in the neighborhood of joints. Fo the rapid removal of the discoloration following contusion, gentle fric tion with alcohol and daily pencilling the part lightly with tincture o iodin will be found useful. In contusion occurring in very lax tissue as in the neighborhood of the eye, aspiration of the effused fluid ma be tried, if the condition is seen early. If tension upon the cavity-wal is such as to prevent absorption, or if blood-coagula fail to disappea through the natural processes of elimination occurring in connectio with new-tissue formation (the so-called clot organization), they mu

be evacuated through an incision. The prolonged presence of such clots in the subcutaneous connective tissue is apt to lead finally to suppuration.

Poisoned Wounds.—Post-mortem or dissection wounds may be taken as a type of infected wounds which exhibit a tendency to special virulency, and are generally considered as a class by themselves. They are characterized by pronounced local and general infection, and are of frequent occurrence among those employed in making autopsies and in dissecting-room students. Wounds received by the surgeon in conducting operations upon infected individuals may give rise to the same train of symptoms. By far the greater number, however, are received in the dead-house, in which case they are usually the result of the examination of bodies recently dead from such infectious diseases as septic peritonitis, erysipelas, pyemia, and septicemia, and give rise to severe and even dangerous symptoms. Comparatively few of these accidents occur among dissecting-room students, for the reason that the infective micro-organisms soon lose their virulency and are replaced by the bacteria of putrefaction. When they do occur under these circumstances, the infection is usually followed by only a very moderate local reaction and comparatively mild symptoms of a general character.

It is unlikely that the special virulency of these cases depends upon any one specific organism, but on the contrary, in the majority of instances the infection is a mixed one, streptococci predominating. This is particularly apt to be the case in infectious processes occurring in surgeons, hospital internes, and nurses from contact with certain cases of cellulitis. It is a well-known fact that some individuals are more susceptible to infection than others; and further, that those who are more or less constantly in contact with infectious material acquire a certain degree of immunity.

While the commonest mode of entrance of the poison is through a wound, this latter need not necessarily be severe or have been received at the time of the inoculation. In fact, it is believed that the infection is oftener conveyed through pre-existent abrasions, slight wounds, and the trifling fissures in the skin occurring at the ungual margins, and known as "hang-nails," than through recent or severe wounds. The reason for this probably resides in the fact that more or less bleeding and inability to continue the work accompany the latter, the poison being thus removed, and prompt measures of disinfection resorted to. Absorption of the poison may occur also through the sweat-glands or sebaceous glands. Those in ill health are more susceptible than robust individuals.

Symptoms.—The most striking characteristics of the hyperacute cases of poisoned wounds are rapidity of development of the local infectious process, accompanied by serosuppurative inflammation and sloughing, and the early supervention of symptoms of systemic poisoning. As a rule, the severity of the latter depends upon the degree and intensity of the former. Occasionally, however, general symptoms of acute septic intoxication, out of all proportion to the local conditions, are observed. In these cases the local signs are often slight. The point of entrance of the infection exhibits a slight edema; a small vesicle filled with serosanguinolent fluid is sometimes observed. As a

rule, there is, however, intense pain at the seat of inoculation. Early collapse supervenes, with rapid and feeble pulse, elevation of temperature, jactitation, subsultus tendinum, and delirium followed by unconsciousness. Death may occur in forty-eight hours. In other cases these symptoms follow the occurrence of acute cellulitis. This condition is ushered in by malaise, local pain, rigors, and vomiting. Swelling of the parts in the neighborhood of the wound, with rapid sloughing of the tissues and early formation of pus, occurs. The cellulitis rapidly extends up the arm to the shoulder, and may even invade the soft parts upon the chest-wall.

In more commonly observed cases, particularly in dissecting-room wounds and in those occurring in surgeons and their assistants, the invasion is of a milder type. The wound becomes painful, red, and but slightly swollen. A papule or pustule develops, and there is but little to attract attention to more remote parts until a series of red lines is discovered running up the arm, marking the spread of infection by the lymphatic vessels. These may sometimes be felt as knotted cords, and may continue to be so felt for a long time following the attack. The lymphatic glands soon become involved. If limited to the superficial group, the glands in front of the elbow, or those above the internal condyle, are affected. If involvement of the deep set occurs, the large glands in the axilla become swollen, painful, and tender. In either case suppuration is apt to follow, although it does not necessarily occur, the process rapidly subsiding. In case glandular abscess follow, the patient will complain of chilly sensations, and a rise in temperature will be observed. With the opening and evacuation of the abscess-cavities the symptoms rapidly disappear. In this class of cases the lymphatic glands interpose a barrier against general infection, acting in conjunction with a high degree of vital resistance on the part of the individual.

In another class of cases, depending upon the virulence of the poison and the degree of resistance of the injured person, the cellulitis may assume the character of an ordinary phlegmonous inflammation with brawniness, excessive pain, a high degree of tension, and diffuse redness of the surface; or these symptoms may be replaced by simple swelling and edema.

The situation and depth of the wound will govern to some extent the rapidity of development of, as well as the routes travelled by, the infection and the symptoms. Wounds penetrating the palmar fascia follow the sheaths of the flexor tendons and lead to suppurative collections above the annular ligament of the wrist. Wounds upon the dorsal aspect of the hand or forearm are of far less serious import.

Treatment.—Prophylaxis is of the first importance. The hands of the postmortemist should be previously smeared with vaselin or lard as a preventive of infection through unobserved abrasions or the glandular structures of the skin. Deeply staining the hands with a fluid made by adding to a 1 : 1000 corrosive-sublimate solution sufficient potassium-permanganate crystals to make a saturated solution of the latter, as originally devised by myself for the purpose of disinfecting the hands of the operating surgeon, may be employed with advantage. The advantage of this method of preparing the hands lies in the fa

that the affinity of the coloring matter of the permanganate for the deeper structures of the skin causes more decided penetration of the latter, both on the part of this agent and of the mercurial compound. The original object in employing this combination in the manner described was the insurance of a more thorough disinfection of the deeper portions of the skin, the stain being permitted to remain during the entire operation. It is afterward removed by immersing the hands in a warm saturated solution of oxalic acid, after which the latter is neutralized by lime water or weak ammonia water. It was soon found that, in addition to this advantage, the surgeons, internes, and nurses employing this method acquired an immunity against the occurrence of so-called "pus fingers" never before enjoyed.

No person should engage in an autopsy who has a palpable wound upon the hand. Hang-nails especially constitute a source of danger. In case a wound, even though it be of a slight nature, is received during an autopsy or in the course of operation upon an infected subject, prompt measures are to be taken to prevent serious consequences. The wounded part is to be isolated from the general circulation by the application of a bandage above. This should be sufficiently tight to prevent the return circulation from taking place, yet not so tight as to interfere with the blood-supply. Bleeding is thus encouraged. The wound is then washed in a 5 per cent. carbolic solution, or a 1 : 1000 sublimate solution, after which the wound is sucked and cauterized with the solid nitrate-of-silver stick, or swabbed with a 30 gr. : ℥j solution of zinc chlorid. The constricting bandage should now be removed and a dressing of gauze wet with a $2\frac{1}{2}$ per cent. solution of carbolic acid, to which has been added tincture of opium in the proportion of an ounce to the pint, applied. The dressings should be moistened occasionally with the same solution.

With the actual occurrence of infection, as shown by the formation of a bleb or pustule at the site of the injury, the surroundings should be thoroughly washed with soap and warm water, disinfected with a 1 : 1000 solution of sublimate, and the pustule opened or the wound freely enlarged, and curetted. If only a bleb is present the cuticle of this is to be trimmed away and the infected area incised freely. Moist warm dressings of the carbolic-and-opium lotion should then be applied. If a cellulitis spread up the arm the latter should be suspended in a hot bath of 1 : 5000 sublimate solution for an hour at a time, this alternating with the warm moist carbolic-and-opium lotion. If the area of infection is large, or if for any other reason it is deemed inadvisable to employ a lotion freely, Bürow's solution may be used. This consists of 5 parts of lead acetate, 25 parts of alum, and 500 parts of water. A hot bath of the latter may also take the place of the sublimate bath. In placing the arm in the bath a hammock-like arrangement should be improvised to prevent constriction due to resting the arm upon the edge of the vessel.

The local conditions should be carefully watched and incisions made from time to time, as needed, to lessen tension, relieve pain, and give exit to purulent material. The incisions should be just deep and extensive enough to effect this object; if carried beyond this point, extension of infection to deeper and more remote parts will be apt to

occur. Infectious processes conveyed along the course of sloughing tendinous sheaths to distant and deeply placed areas require the excision of the sheaths as well as of the tendons themselves. While this course is always to be deprecated, leading as it does to irreparable loss of function, it is to be preferred to the risks involved in permitting virulent infection to reach inaccessible parts. Amputation may even be required.

The general treatment consists of forced nourishment, the free use of alcoholic stimulants, and the administration of quinin in doses of 5 or more grains, combined with the tincture of the chlorid of iron. The more threatening the septic intoxication the more urgently these measures are demanded. Experience tends to encourage the use of antistreptococcic serum in these cases in the same manner as in septic peritonitis, viz., 20 c.c. of the Marmorek serum injected in the region of the buttocks, and repeated in 10 c.c. doses every six hours until amelioration of the symptoms is noted or the case is decidedly a hopeless one. Diarrhea, which is apt to occur, should be held in check. If pain is excessive and not relieved by the local applications, morphin is to be employed hypodermically. During convalescence the patient should be carefully nourished, and change of air and surroundings recommended.

Anatomical Tubercle.—This is a name applied to a chronic thickening of isolated portions of the back of the hand, over the knuckles and metacarpal bones, occurring among those who habitually handle the dead bodies of either men or animals. It seems to be particularly prone to occur in these regions on account of the thin skin over the latter; occasionally, although very rarely, it has been found upon the forearm, and has been observed upon the borders of the nails, as well as upon cicatrices marking the site of old post-mortem wounds. In former times, on account of its resemblance to lupus, it was known as lupus anatomicus, and recent investigations seem to show that the condition is actually an inoculation of the tubercle bacillus. There is no evidence, however, that generalization of the infection ever occurs from this source. It is probable, therefore, that all cases are not of a specific nature, but that the majority of these are the result of constant contact with putrid animal matter.

The tubercles themselves resemble common warts, and consist of papular growths, made up of enlargements of the cutaneous papilla occurring in circumscribed limits, and forming small tender areas with uneven surfaces. These, upon being irritated, furnish a thin serum which upon drying forms a scab. They are covered with a layer of thickened and opaque epidermis of a bluish-red color. On the border of the nails the affection occurs as isolated nodules. In some instance the disease takes the form of an eczema, such as is found upon th knuckles of plasterers. The course of the affection is essentially chronic one, with a tendency to recovery when the exciting cause i removed.

The treatment consists in the removal of the cause, either by protecting the hands with rubber gloves or discontinuing the work altogether. If persistent in spite of these measures, the application of th acid nitrate of mercury or fuming nitric acid will accomplish the

removal. In case of extensive involvement of the back of the hand the parts should be thoroughly curetted and dressed with Bürow's solution, or the borosalicylic solution of Prof. Thiersch.

Modifying Influences Affecting Repair.—*Hygienic conditions* exert a modifying influence upon the healing of wounds. They include the relations which climatic and atmospheric conditions, temperature, sunlight, and food bear to the general well-being of the individual. In those countries in which, from the continued high temperature, an out-of-door life on the part of the inhabitants is necessary, healing takes place more readily than among those living where cold weather and dampness prevail. Again, moderately warm weather indirectly favors repair by the necessity that exists for keeping the doors and windows open, thus insuring a constant supply of fresh air, as well as sunlight. With changing barometric conditions the mortality from injuries and operations is said to vary greatly.

According to Hewson's observations, based upon a study of the meteorological records and the records of the surgical service of the Pennsylvania Hospital extending over a period of thirty years, the lowest mortality occurred with a rising barometer. This was nearly doubled with a stationary barometer, and with a falling barometer it was more than doubled. The low barometrical pressure bore a direct relation to general infection from local septic conditions in wounds.

The necessity of a liberal supply of sunlight and fresh air cannot be too strongly emphasized, nor can the influence of these upon nutrition be overestimated, particularly under conditions in which there is depression of the vital powers. The processes of repair which take place in the tissues have been likened to those occurring in the growing child (Pilcher). The effects of sunlight and fresh air have always been matters of common observation, and mark an instinctive craving for these aids to healthy development exhibited by all living creatures. Their presence reinforces the general powers of resistance on the part of the individual; while their absence, particularly the absence of a liberal supply of fresh air, not only entails a lessening of this quality already possessed by the patient, but likewise leads to an increased accumulation of infectious matters from the bodily exhalations of the patient, of those in attendance upon him, and of others confined in the same ward. The necessity for measures to provide fresh air to those in health emphasizes the importance of redoubling these measures in the case of the injured.

The necessity for a good supply of nourishing and easily digested food should be insisted upon, for in the absence of it wounds do not heal quickly. Under circumstances of limited supply of food-material, particularly if the food is of a coarse and unwholesome character, and perhaps badly cooked as well, the reparative process will be arrested, and retrogressive and degenerative changes initiated and perpetuated. The digestive powers of the injured person should be carefully studied, and the important influences of diet upon his early restoration to health and usefulness should be thoroughly appreciated by the surgeon.

The Mental State.—The importance of maintaining cheerful surroundings has not met with the attention which it deserves. It is a well-known fact that the wounds of those defeated in battle heal much less readily than those of a victorious army. The influence of the mind

upon the body is such that the reparative processes are more or less influenced by mental conditions. Observations in the wards of large metropolitan hospitals constantly impress one with these facts. Those patients who have recently landed from emigrant ships, with no homes established in this country, as well as those brought from lodging-houses and having neither home nor friends, heal slowly, in spite of improvement in their bodily condition arising from proper hygienic surroundings and better food. This can be reasonably attributed to anxiety and fear as to their future. On the other hand, healing is undoubtedly promoted by the opposite conditions of hope and confidence, as exhibited by those who receive the visits of cheerful friends and look forward to return to their poor but happy homes.

Age.—The healing of wounds is accomplished with much greater facility in the young than in those in middle life, or the aged. This is due, first, to the fact that the reparative power is greater; and second, to the greater freedom from pre-existing organic disease. As a general rule, it may be stated that the healing power progressively diminishes after the thirtieth year of life. Large wounds heal slowly in the aged, who are apt to succumb to slight causes while the reparative process is in progress. On the other hand, wounds heal promptly in the young, and parts which in those of more advanced age require removal because of an excessive crushing effect, in young patients regain their vitality, and finally their function, in a most astonishing manner, and that, apparently, without noticeable drain upon the patient's vital resources.

Constitutional and Diseased Conditions.—Under this head are to be grouped nutritive disturbances due to actual disease, and to genera states of the blood which do not necessarily constitute a recognizabl disease. Marked anemia, on the one hand, and plethora, upon th other; the direct effects of starvation upon the tissues, and the result of gluttony; conditions arising from the excessive use of alcoholi stimulants; the exhaustion from overwork and intellectual strain—al of these, as well as the effect upon bodily nutrition of vicious habit and such other influences as tend to lower the general vital resistanc should be taken at their full value in estimating the prognosis in ind vidual cases of extensive wounds.

The most serious of the complications of the general system t which wounds are subject are those arising from the pre-existence c *pyemia* and *septicemia.* The presence of a local and virulent infectio such as *erysipelas*, adds a special source of danger. *Local suppurati conditions* in parts subsequently subjected to accidental wounds lead t infection of the latter as well as to a spread of the original suppuratio Differences between accidental and operation wounds reside in the fa that the latter are incised wounds with clean-cut edges, and are plann with the view of evacuating collections of pus and relieving tensio while the former are usually of a contused or lacerated character. Tl latter inflict great damage upon surrounding structures, thus invitir spread of pre-existing suppurative conditions.

Certain diseases which give rise to general defects of nutrition i terfere greatly with the healing of wounds, and measures to comb these should be instituted early. Among these may be mention

tuberculosis, syphilis, diabetes mellitus, and *malaria.* In the presence of these complications the surgical clinician will find ample opportunity of drawing upon his therapeutic resources in promoting prompt healing. Of still greater importance, because of greater difficulties of management, is the presence of *organic changes in important organs,* such as the lungs, heart, liver, and kidneys. The three last-named organs are frequently the subjects of interdependent disease, and when a well-defined pathologic change is discovered in the one, the two others should be made the subject of careful investigation. The seriousness of these organic diseases, in addition to the relation which their stage of advancement at the time of the infliction of the wound bears to the healing of the latter, arises from the fact that the pre-existing affection is temporarily at least, and frequently permanently, aggravated by the injury. This may be the direct cause of death, and failure to recognize and provide against such a contingency in cases of personal assaults where the wounds received are of themselves insufficient to cause death, may lead to serious medico-legal complications.

BURNS AND SCALDS.

Certain chemical and physical effects occur as the result of exposure of portions of the body to excessive heat. To this class also belong injuries caused by caustic substances, such as concentrated acids and caustic alkalies. Disturbances consisting of changes in the skin and circulatory channels, and varying according to the temperature and length of time of exposure of the part, are observed. The inflammatory conditions present are not essential, but accessory.

Degrees of Burns.—A momentary exposure to a temperature somewhat below the boiling point of water produces an overfilling of the smaller arteries, due to a simple paralysis of the constrictor muscles of these. The resulting increased quantity of blood in the parts occasions the hyperemia or redness observed under these circumstances. This is known as a *burn of the first degree.*

Burns of the second degree include those in which blistering takes place. Here there is an exudation of serous fluid into the tissues, particularly the rete Malpighii. A portion of the epidermal layer is lifted up, constituting the covering of the blister.

Burns of the third degree are the result of albuminous coagulation affecting the contents of the vessels and the serous fluid and albuminous substance of the tissues. Greater or less areas are deprived of nourishment, and necrosis of tissue follows. An exaggeration of this degree constitutes the fourth and fifth degrees of some authors, these terms being applied to either charring of the skin or of the skin and the muscular structures as well.

Inflammatory Conditions Following Burns.—The condition of hyperemia which occurs in burns of the first degree somewhat resembles an inflammation. This hyperemia, however, disappears spontaneously after a comparatively short time. In cases, however, of burns of the second or third degree the situation is vastly changed, opportunity being afforded for the entrance and propagation of bacteria. In burns of the second degree, if the vesicles are not disturbed,

healing may take place beneath the raised layer constituting the surface of the blister. When these are ruptured, more or less infection and inflammatory complications may follow, as a consequence. In burns of the third degree the infection takes place from the margins of the burn, which, as a rule, are not carbonized, and not from the area of charred tissue, since here the usual and readiest channels of infection are closed. From the margins of the eschar a slowly progressing suppurative inflammation goes on, the neighboring structures partaking of this to a greater or less extent. By means of this *suppuration of demarcation*, as it is called, the necrotic tissue is slowly lifted up and separated from the living structures beneath. This suppuration of demarcation may give place to a phlegmonous inflammatory condition in which case the line of demarcation is not formed, but a necrosis of inflammatory origin may become associated with that arising from the burn. In this manner large areas of tissue sometimes become involved in the gangrenous process. The suppuration of demarcation is not always marked. The charred portion is not a favorable soil for the development of bacteria, owing to the fact of the coagulation of its albuminous elements. If efforts to prevent the entrance of bacteria at the margins by the early employment of antiseptic measures prove successful, the entire separation of the necrotic portion may occur with scarcely a trace of suppuration. The formation of new vessels goes rapidly forward, and the young vascular connective tissue crowds toward the necrotic tissue. In this way an aseptic granulation-process replaces the suppuration of demarcation, and a process of elimination of the dead part follows. This eliminative process occasionally takes a very long time, particularly in cases in which bone is involved. It may demand artificial aid. Following the separation and removal of the necrotic tissue a correspondingly large granulating wound is present, which gradually becomes covered in as a skin-defect. The cicatrices following burns are apt to give rise to serious deformities as well as to various disturbances of function, such, for instance, as permanent flexure of the joints in the extremities, ectropion of the eyelids, etc.

Constitutional Symptoms.—In cases of extensive burns the patient usually complains of great pain in the original part, although in carbonization of an entire extremity comparatively slight pain may be felt, the burned area and its neighborhood being almost completely anesthetic in the commencement. The patient is usually in a state of great mental excitement, is very restless and tosses about in bed, screaming and crying with combined fright and pain; in other cases he lies in an apathetic state. In rapidly fatal cases delirium and convulsive movements come on early, with extremely rapid and thready pulse and subnormal temperature. Vomiting and intense thirst are pronounced symptoms in these cases. The urine is scanty; complete suppression may occur. The renal secretion is not infrequently reddened from the presence of hemoglobin. The cause of the latter is the destruction of the red blood-corpuscles which were in the vessels of the affected part at the time of burning.

The patient may rally from the first shock and give promise of recovery for the first few days, only to develop the above symptoms in the stage of inflammatory reaction. He may perish within a few hours

of their appearance, or he may linger on only to succumb finally to some of the complicating sequelæ. (See Prognosis.)

Prognosis.—In young children burns of the first degree, even if of but limited extent, may prove fatal. Still smaller areas of the second and third degrees may also result fatally. The involvement of large areas of the surface of the body in burns of the second and third degrees involve direct danger to life. In the adult, if more than two-thirds of the surface is involved in a burn of the first degree, life is usually destroyed; while if one-third of the surface is burned to the second or third degree, death will almost inevitably result. The locality of the burn should be taken into account in stating the prognosis. Burns about the thoracic and abdominal regions are to be regarded more seriously than those of comparatively larger area or greater severity elsewhere.

Death following burns may result directly from shock. Reflex cardiac paralysis may be due to over-stimulation of the superficial sensory nerves. When, on the other hand, reaction is established, congestion of internal organs is to be feared. This may result from vasomotor paresis, or from blood-stasis due to excessive destruction of red blood-corpuscles and their conversion into small globules. The secondary dangers relate to prolonged suppuration, exhaustion, erysipelas, pyemia, septicemia, and tetanus. Scalds of the mouth and fauces may be followed by edema of the glottis.

The Treatment of Burns.—The local treatment of burns of the first degree is mainly directed to the alleviation of the pain. This may be accomplished best by dusting over the parts with powdered starch or zinc oxid, enveloping afterward in cotton wool, and elevating, if the part affected be a limb. If the pain is excessive it may be allayed by the hypodermic use of morphin. The application of an ice-bag, or lead-water compresses with ice, is useful.

In burns of the second degree the extent and severity of the resulting inflammatory complications will be in direct proportion to the amount of infection which occurs. Therefore, where there is the slightest vesication the practitioner should bear in mind the necessity for early aseptic and antiseptic measures. Blebs should be evacuated, when tense, through punctures, but the elevated epidermis should not be removed. Cleansing of the burned area is indicated, followed by antiseptic irrigation (1 : 1000 bichlorid solution, or 3 per cent. carbolic solution), and the application of an antiseptic powder dressing, such as iodoform, zinc oxid, bismuth subnitrate, boric acid, etc. The whole may be covered with sterilized non-absorbent cotton and bandaged with gauze rollers. Nitzche's linseed-oil varnish consists of 1 part of lead oxid dissolved in 25 parts of boiled linseed oil, to which is added, while the oil is hot, 5 or 10 per cent. of salicylic acid. This is painted over the burn after the part has been carefully disinfected, and is covered by cotton wool held firmly in place by a bandage. Whatever dressing is employed, the same rule as regards redressing holds good here as elsewhere—namely, unless special indications exist demanding it, the less often redressing is done the better. In extensive burns the permanent warm bath may sometimes be employed with advantage.

In cases in which extensive and deeply burned areas are present,

involving, for instance, a considerable portion of a limb, removal by amputation will become necessary. The amputation should be performed as soon as possible after the symptoms of shock have subsided. The removal of sloughs is always indicated, and should be practised wherever feasible, both in order to get rid of the putrefying masses as rapidly as possible, as well as to obtain access to the parts beneath for the purposes of a more thorough antisepsis. The poisonous nature of many antiseptics should be borne in mind, and caution should be exercised in making applications to extensively denuded or large granulating surfaces. Borosalicylic solution (Thiersch's) for moist dressings, and simple salicylic gauze for dry dressings, fulfil most of the indications, and are comparatively safe. The covering of large granulating surfaces with skin can be hastened by the Thiersch method of skin-transplantation. This, as well as the method of transplanting large skin-flaps with pedicles, constitutes the best method of preventing cicatricial deformities resulting from contractures or adhesions. If these have occurred, they should be treated by excision of the cicatrix and closure of the defect by one of the above-mentioned methods of skin-grafting.

In very extensive burns involving a large portion of the body attention to the general condition is demanded. Here supporting measures and remedies designed to relieve pain form necessary adjuvants to the local treatment. Profound collapse may occur, and should be met by the administration of hot alcoholic drinks, black coffee, etc. The patient is to be wrapped in warm blankets, and morphin given hypodermically to allay pain and restlessness. Autotransfusion (enveloping the limbs in elastic bandages to drive more blood to the heart) may be useful. Subcutaneous salt infusion has been recommended.

EFFECTS OF LIGHTNING.

Lightning-stroke is the passage of an aërial current of electricity through the body. It may be direct, as, for instance, when the body receives the direct electrical discharge; or indirect, when air-induced electrical shock occurs in the body, direct discharge being received by some contiguous object, as a tree.

The accident occurs with greater frequency in sparsely-settled districts and where there are comparatively few objects, such as trees, tall buildings, etc., which serve to convey the electrical currents in the atmosphere to the earth in divided portions rather than in an accumulated discharge. The great majority of individuals affected are struck while at work in the open fields, although it may happen at sea, and even to divers at work beneath the water. The annual loss of life throughout the world from lightning-stroke is very great.

Those subjected to direct lightning-stroke perish almost immediately, in the vast majority of cases. Including all cases, both direct and indirect, 72 per cent. prove fatal.

The effects of lightning upon the organism differ, according to whether the purely electrical or the burning action predominates. In direct stroke the effects are sometimes most extraordinary. In addition to the burning, which may vary from a simple drying of the e

dermis to extensive and deep burns, there may be a tearing, lacerating action, which sometimes produces the most terrible destruction, such as the rupture of large vessels, and even the complete severing of a limb from the body. There is also paralysis of respiration and circulation. In some instances of indirect stroke the effect is similar to that produced by exposure to the current from a dynamo. For a given individual in a normal condition of health a definite amount of electrical energy, of whatever kind it be, will produce fatal results. The infliction of a violent electric shock upon the nerve-centers governing respiration results in a suspension of the latter, just as in extreme cerebral concussion. In addition to this the effect of the electricity is to contract the arteries and increase the blood-pressure. Experiments made upon dogs seem to show that the mere passage of a current sufficient to cause death does not produce any anatomical disintegration (Bleile). Certain edematous and elevated branching lines of a brownish-red color are sometimes observed diverging in a zigzag direction from the point where the current is supposed to have entered the body, constituting the so-called lightning-marks (Fig. 31).

FIG. 31.—Lightning-marks.

These, according to Rollet, are the result of the setting free of the coloring matter from the red blood-corpuscles in the line of the lightning-stroke, the coloring matter transuding through the walls of the vessels and their branches.

Symptoms.—When the lightning-stroke is not immediately fatal, the patient suffers all the phenomena of profound shock. Semi-unconsciousness, or even profound coma, may last from a few hours to several days. Localized anesthesia, paralysis, dysphagia, disturbances

of vision, and other nervous phenomena are observed. These, with the exception of the visual symptoms, are usually transitory. Lightning-paralysis is generally recovered from in a few days or weeks, save when the paralysis is only indirectly due to the lightning-stroke, the direct cause being a hemorrhage into the brain or spinal cord. The first stage of lightning-paralysis is characterized by direct injury to the nerves or muscles; in the second stage there are present the conditions of a traumatic neurosis. In cases which eventually prove fatal, death results from cerebral hemorrhagic or other effusion, from hemorrhage from ruptured vessels elsewhere than in the brain, from the shock of the severe injuries sustained, or from the ultimate effects of the injuries.

Treatment.—The constitutional symptoms, shock, etc., of lightning are to be treated symptomatically. Such stimulating measures as hypodermic injections of strychnin, small doses of morphin, strong coffee, either per os or per rectum, should be employed.

SHOCK.

Syncope and Collapse.—The terms *syncope* and *collapse* represent conditions which, surgically considered, are generally more or less allied. For convenience of study, as well as for all practical purposes, syncope, with its fainting, pallor, and temporary unconsciousness, may be considered as the first, and collapse, with its extreme impairment of all the vital processes occurring as the precursor of death, may be considered as the last stage of the condition known as shock. The condition of syncope may be so profound, however, that consciousness is not regained, the patient passing directly into the stage of collapse without the occurrence of the intermediate stage.

Shock.—Shock is a peculiar state of reflex depression of the vita functions, especially of the circulation. It is suddenly developed, as a rule, and is due to nervous exhaustion resulting from severe irritation of the peripheral ends of sensory and sympathetic nerves following an injury. The condition is essentially one of inhibition of nerve force and reflex paralysis. There is apparently exhaustion of th medulla oblongata and spinal cord, followed by marked lowering o the vital powers. Goltz's experiments show that paralysis of the vaso motor centers in the medulla is the essential feature, and that this i produced in a reflex manner by violent disturbances of the sensor nerves. Mechanical irritation or stimulation of the sensory nerve temporarily lessens the activity of the corresponding nerve-center which become, according to the extent of the irritation and degree c the reflex, either altered, weakened, or paralyzed. The varying degree of shock, therefore, are dependent upon the severity of the irritatio as well as upon the length of time which this continues in existenc These degrees may range from a mere temporary faintness from anem of the brain, lasting only a few moments (syncope), to a profound, co tinued, and finally fatal, suspension of function or vital depressi (collapse).

With diminution or paralysis of the vascular tone, particularly the arteries, and the coincident weakness of the heart's action, t blood is unequally distributed, and the circulatory balance is disturb

The veins, particularly those of the abdomen, become overfilled from gravitation, the right side of the heart becomes gradually distended, and the quantity of blood in the arteries is correspondingly lessened. As a result of this the lungs and brain suffer from anemia, and, in the event of the condition persisting, the heart's action ceases.

The conditions of pain, fear, and shock, though apparently widely different, have much in common. The same pupillary, respiratory, voluntary motor, cardiomuscular, nutritive, and psychical phenomena, are common to all three.

In addition to the above condition, which is spoken of as corporeal shock, there is another form, in which the depression is due to emotional causes, and which is known as psychic shock. Finally, both may be combined in a case of shock.

Symptoms.—These may supervene almost immediately upon the reception of an injury, or toward the close of an operation. In the latter case they may either make their first appearance upon the occurrence of a sudden or large loss of blood, or else the symptoms may come on insidiously (delayed shock). The characteristic symptoms are pallor of the skin and visible mucous membranes; loss of facial expression; eyes dull and pupils dilated, only slowly reacting to light; head bathed in a cold perspiration; complete muscular relaxation; feeble, irregular, and sighing respirations; delayed, irregular, and weakened heart-action; diminished sensibility, the patient ceasing to complain of pain, and sometimes semi-unconsciousness; coldness of the expired breath and of the surface of the body; subnormal body-temperature; and mental torpor. Occasionally nausea and vomiting are observed.

The above symptoms are present in the majority of cases, and constitute what is known as the apathetic or torpid form of shock. The mental torpor is sometimes replaced by a more active train of symptoms. Under these circumstances the patient is excited and restless, tossing himself around in the bed, and shrieking and crying out in maniacal delirium. During all this time he may have a thready or almost imperceptible pulse, and irregular, shallow respirations.

The pallor and coldness of the surface in shock are due to alterations in nutrition which depend, in their turn, upon trophic disturbances. The arrest of tissue-metamorphosis leads to respiratory disturbances, the blood, through loss of its nourishing properties, being no longer capable of properly stimulating the respiratory centers. Reflex mydriasis is always present in any painful irritation, and is due to overstimulation of the sensitive nerves. The muscular relaxation, or weakness of the voluntary muscular system, is due to inhibition of the motor centers following peripheral irritation, and is analogous to the arrest of the respiratory muscles on the affected side in pleuropneumonia (Likorsky). The cardiomuscular symptoms emphasize the peculiar and especial sensitiveness of the vasomotors. Vascular spasm is soon followed by vasomotor paralysis. A fall of blood-pressure and diminution of the number and strength of the heart-pulsations follow. The mental apathy is due to the depression of the psychical, as the other symptoms to that of the physiological, functions.

In the cases in which the supposed shock comes on more gradu-

ally, the symptoms may really be due to hemorrhage. The condition of delayed shock is said to occur in cases in which the patient was exposed to great danger, and yet escaped with slight physical harm. The patient may give a history of being able to move about at first without much difficulty, the shock supervening insidiously. Symptoms due to delayed shock are rarely, if ever, observed following operative procedures. They do, however, occur rather frequently following railroad accidents, and form a basis for some of the cases of so-called traumatic neuroses which often constitute part of the contention in suits to recover damages for personal injuries. In this class of cases there is frequently room for suspicion of exaggeration, if not of downright simulation.

The condition of shock may persist for from two to twenty-four hours. The *stage of reaction* is announced by improvement in the pulse, both as regards its rapidity and strength, and a more or less pronounced rise in temperature. Should the latter exceed the normal, as it frequently does, it will soon fall again. The formerly much dreaded "excessive reaction" following the shock of operation is now known to be due to septic inflammatory conditions, and is rarely encountered, comparatively speaking. The recovery, in uncomplicated cases of shock, is usually rapid. In the course of a few hours the improvement is so pronounced that danger from this source is no longe to be feared. Mental symptoms, however, sometimes persist for longer or shorter time; though perfect recovery takes place eventually.

In cases complicated with large losses of blood and severe injurie to important parts, particularly the brain, as well as cases of prolonge and severe operative procedures involving vital organs, the conditio of shock may pass into that of collapse and end in death. Temperature observations should be carefully made. If the fall of temperatur following an operation is but one degree or less, recovery will probabl ensue; if three or more degrees, a fatal result may be expected.

Diagnosis.—As between corporeal and psychic shock the histor of the case will establish the diagnosis. Shock from purely emotion causes is rarely so profound and prolonged as to involve danger to lif Those more common nervous conditions involving manifestations o extreme fright, as well as those symptoms which occur from dangerou chloroform or ether narcosis or which follow severe hemorrhage, a to be carefully differentiated from true shock.

Shock should be carefully diagnosed from fat-embolism. Its o currence immediately after the injury, as a rule, as compared to t period at which the symptoms of fat-embolism make their appearance—namely, from thirty-six hours to three days, will serve to differentia the two conditions.

Treatment of Shock.—As a routine measure for the preventi of post-operative shock, the patient should be kept warm in bed f several hours before the operation. As cardiac stimulants a $\frac{1}{20}$-gra dose of strychnin and 3 grains of caffein citrate should be given hyp dermically an hour beforehand, as a part of the routine of preparatio A cup of hot, strong coffee may also be given at this time with adva tage, to prevent the depressing effects of the ether. Opium by t

mouth, or, better still, morphin hypodermically, is urged by some as a useful preliminary measure to fortify the heart and nervous system. The operating-room should be warm, and the operating-table may be heated by hot-water bottles. One of the especially constructed tables designed to keep up artificial heat during the operation may be employed.

Much may be done in preventing shock by the method of conducting the operation itself. The tendency of modern surgery, with its many and often unnecessarily elaborate details of antiseptic technic, is to encourage the occurrence of shock. The employment of dry sterilized towels and sheets to isolate the field of operation rather than those wet with antiseptic solutions, is to be preferred, in order to prevent the undue abstraction of heat. For the same reason dry methods of operating, and the avoidance of irrigation as much as possible, should be insisted upon. The trunk in particular is to be protected against chilling, only a sufficient portion being exposed for the purpose of the operation. The lower extremities, when not the object of operative attack, should be covered with warm stockings and drawers or bandaged with cotton wadding and flannel rollers. Prolonged exposures of such organs as the brain or intestines will serve to induce shock. During all long operations, the employment of a hot stimulating enema (whiskey and water) is advisable, without waiting for the development of symptoms of shock. With the perfect system of installation and organization which marks the modern well-equipped hospital, and that simplification of operative technic which aims to accomplish the desired object in the shortest possible space of time, the precision of the surgery of to-day may be so combined with the speed which characterized the surgery of the past generation, that post-operative shock will be as rare an occurrence as post-operative sepsis.

If there is especial reason to fear the supervention of dangerous shock in any given case of contemplated operation, the suggestion of Professor Stephen Smith may be followed of stimulating the patient for several hours beforehand by means of hot alcoholic drinks. An ounce of brandy or whiskey is to be given in a glass of hot milk ten hours before the time appointed for the operation, and repeated two or three times at intervals of two hours, unless symptoms of intoxication appear. The method of storing blood in the extremities by the preliminary application of a tourniquet, with the view of permitting the blood to escape into the general circulation in an emergency during the operation, although of service in cases of hemorrhage and in dangerous chloroform narcosis, is of doubtful utility as a preventive of shock.

When the conditions of extreme shock are present following an injury, the administration of an anesthetic is contraindicated. The effect of the anesthetic may be sufficient to stop completely the pulsations of an already weakened heart-action. Whatever operative procedure is absolutely necessary, as, for instance, for arrest of hemorrhage, should be carried out without an anesthetic.

In the treatment of shock the patient should be laid flat upon his back and the entire body tilted, head downward, to a decided angle. Should venous congestion of the face occur while the patient is in this

position, the latter may be modified, or the body placed upon a level if necessary. Blood should be forced into the more vital parts by rubbing-movements in the direction of the trunk. Dry heat is to be applied, but caution should be observed not to expose the patient to the danger of burns. Sinapisms may be applied to the extremities; but should be used cautiously, for the reason that over-stimulation of the peripheral-nerve distribution may result in increasing the shock. Cloths wrung out of hot mustard water may be applied to the precordial region. If the patient can swallow, warm stimulating drinks should be given—strong coffee, wine, or whiskey and water, as hot as can be taken. If he is unable to swallow, or there is risk of the fluids passing into the larynx, these should be given by enema. An enema consisting of an ounce of whiskey, from 3 to 6 grains of musk, and 15 or 20 drops of tincture of opium, added to a cup of strong coffee and thrown into the rectum is of great value. In the meanwhile, available remedies designed to stimulate the heart's action and the respiratory centers are to be given hypodermically. Of these the most valuable are strychnin and atropin. The former may be given in $\frac{1}{20}$-, or even $\frac{1}{10}$-grain, and the latter in $\frac{1}{60}$-grain doses. Camphor dissolved in ether and extract of calabar bean are also recommended. Nitroglycerin in $\frac{1}{100}$-grain doses hypodermically and inhalations of amyl nitrite, particularly the latter, are stated, upon theoretical grounds, to aid in the relief of the vasomotor spasm of the cerebral capillaries. The dose of amyl nitrite by inhalation can scarcely be accurately regulated, but a few drops may be placed upon the corner of a napkin and inhaled. If marked flushing of the face occurs the remedy is said to have accomplished its object. I have never observed marked evidences of benefit from the use of this drug. The fumes of strong ammonia are to be employed with caution.

Tincture of digitalis is to be given by the mouth in 10-drop doses, whenever possible. The patient can usually take care of it, if it be administered drop by drop upon the back of the tongue and allowed to trickle down the throat. In the event of failure to administer it in this way, it may be given hypodermically, after dilution (1 to 4 parts) with whiskey.

In the employment of these powerful drugs the possibility of their failure to act for a certain length of time, after which a cumulative effect may result, should be borne in mind to the end that caution be exercised not to repeat the dosage too often or at too short intervals. In this connection the experiments of Roger are interesting. This observer produced the condition of shock in frogs by means of the discharge from a Leyden jar, and noted the interesting fact that the spinal cord and muscular apparatus became insensitive to the stimuli which affect these structures ordinarily, as, for instance, strychnin in the case of the spinal cord, and veratrin in that of the muscles. Either the tissues are unable to react, which can scarcely be true of the muscles, or, more probably, the stimulating agent does not pass from the blood to the tissues. Failure of absorption cannot explain it, since the agents are found circulating with the blood. These observations throw some light upon the well-known fact that powerful stimulating remedies frequently fail to act in the presence of profound shock

With the subsidence of the conditions which prevent them from acting, the drugs, after repeated administration of the usual remedial dose, may exert a toxic effect.

If death threatens from failure of the respiratory act, in addition to hypodermic injections of atropin, artificial respiration may be practised. In addition to this the phrenic nerve may be subjected to faradization, one pole of the induction coil being applied over the phrenic nerve at the root of the neck, and the other at the diaphragm.

In cases of the so-called erethistic or restless type, in addition to the employment of the usual remedial measures, the administration of morphin in $\frac{1}{6}$-grain doses will be of great value. Undue and sudden reaction is sometimes observed in this class of cases, and should be carefully guarded against.

Saline infusion should be reserved for cases in which there has been large loss of blood. In simpler and uncomplicated shock it can only add to the already great embarrassment of the circulation. It may be of benefit when the shock has lasted for several hours and coagulation of blood in the pulmonary vessels is to be feared, since it will aid in preventing this.

FAT-EMBOLISM.

During life the fat-globules of the body represent a drop of oil enclosed in a vesicle. Under the circumstances of an extensive crushing injury a certain amount of fat may enter the circulation through veins which are coincidently injured, or by absorption of the lymph-channels. The fat, in the great majority of cases, is the medullary substance of a bone, which has become broken up in connection with multiple fractures, or the crushing of a simple large bone. The fat may also be supplied by the subcutaneous layer, the liver, brain, etc. Whatever the source, the condition is almost always due to traumatism. The instances in which it has its origin in inflammatory or degenerative conditions are rare. Osteomyelitis is said to produce it. Fat-embolism is more apt to occur in injuries to bones for the reason that, not only is there a large amount of fat in the medulla, but large veins which do not easily collapse are also present. Fat-embolism probably occurs to a greater or less extent in every case of fracture, and in many other traumatisms as well—viz., lacerations of the soft parts, rupture of fatty liver, surgical operative procedures, etc.

Upon entering the circulation the fat is first carried to the lungs, where the larger part of it remains. A portion of the fat, however, may traverse the pulmonary capillaries and be arrested in the brain, the spinal cord, the kidneys, the muscular structure of the heart, and other organs. Blocking of the capillary circulation in the lungs may result from an abundance of fat and from high arterial pressure. In the case of the kidneys the fat passes into the capillaries of the glomeruli and is excreted by the urine. The fat may likewise be found in the bile. Small ecchymotic hemorrhages in the liver and brain are sometimes found post-mortem. Occlusion of the blood-vessels of the myocardium by the fat results in a fatty degeneration which sometimes may be detected macroscopically in the shape of dull spots.

Symptoms.—The symptoms of fat-embolism may appear as early

as thirty-six hours after the injury (Park), or they may be postponed to the fifth day. The countenance is at first pale, and the facial expression anxious. The arrest of fat in the pulmonary circulation produces dyspnea and rapid breathing, and finally cyanosis. This may be associated with Cheyne-Stokes respiration, with muscular twitchings, and paralysis of certain muscles suggesting cerebral edema as a complication. Symptoms of edema of the lungs are present, and in some instances foam tinged with blood issues from the mouth. Hemoptysis is only of occasional occurrence. The heart's action is increased and becomes irregular, and there may be a rise of temperature, but this is not characteristic. There is usually at first mental excitement, but this soon gives place to somnolency, and, in fatal cases, to coma. Fat-globules are found in the urine.

Diagnosis.—This condition will be suspected if the group of symptoms described comes on after any injury involving the bony structures, and perhaps in other extensive injuries as well. The symptoms should not be mistaken for shock following fracture, nor for pulmonary embolism. The time of the occurrence of the symptoms will aid in the differential diagnosis. The shock following a fracture usually develops within the first three hours, and is rarely delayed beyond this time; fat-embolism may occur in exceptional instances as early as thirty-six hours, but as a rule it is delayed for three days; pulmonary embolism is an occasional complication of fracture occurring in the third week, and depends upon the displacement of a portion of a thrombus following injury to a vein, the loosened portion migrating to the lung and causing death by obstructing the pulmonary artery. In general terms, therefore, the time for the occurrence of these complicating sequelæ in fractures is, for shock three hours, for fat-embolism three days, and for pulmonary embolism three weeks (Dennis). Exceptionally, the supply of fat may be intermittent and occur at different stages of the repair (Heuter-Lossen).

The elimination of the fat by the urine after being forced throug[h] the lungs and carried thence to the kidneys forms the basis for th[e] most valuable diagnostic point in this condition. The fat is foun[d] floating upon the surface of the urine in the shape of oil-like drop[s]. In doubtful cases in which the symptoms are cerebral and cardia[c] rather than markedly pulmonary in character, the discovery of fat [in] the urine is positive evidence of fat-embolism. In cases in which th[e] classical symptoms of difficult respiration and embarrassed heart-actio[n] are present, the presence of fat in the urine completes the clinic[al] picture.

Prognosis.—Although fat-embolism may terminate fatally, dea[th] from this cause alone occurs but rarely. Mech,[1] however, has collect[ed] 15 cases in which every other cause of death could be exclude[d]. Experiments made upon animals show that an amount of fat equal [to] three times that contained in the thigh, slowly injected, is necessary [to] produce death; injected rapidly a smaller amount suffices (Ribber[t]). Death usually takes place from interference with the circulation, [al]though Scriba asserts that the fatal result is invariably due to chang[es] in the central nervous system. The cardiac lesions found upon autop[sy]

[1] Ribbert, of Zurich: Correspondenz-blatt für schweizer Aertze, Basel, August 1, 18

are always associated with pulmonary and cerebral conditions sufficient of themselves to cause death; there is therefore no means of determining whether or not these alone are competent to bring about a fatal issue.

Treatment.—The first indication is absolute physiological rest of the injured parts, to prevent further breaking up and dissemination of fat. This must be secured at all hazards, forced mechanical restraint being employed if the patient's state demands it, as, for instance, in conditions of delirium, etc. The next most important indication relates to the stimulation of the heart's action, in order that the fat may be forced from the venous to the arterial system, where it may undergo either oxygenation or saponification through the medium of the alkaline constituents of the blood. The ordinary cardiac stimulants, such as alcohol, digitalis, and strychnin, are to be employed. In addition to these, inhalations of oxygen may be useful (Park). Cupping will assist in relieving the dyspnea. The administration of ether in the form of Hoffman's anodyne, or its use by hypodermic injection, is suggested. Finally, in cases in which there is extensive comminution of bone, making it difficult to maintain the parts at perfect rest, continued disintegration and entrance of fat into the circulation may constitute a vital indication for amputation.

THE REPAIR OF SPECIAL TISSUES.

The Skin and Subcutaneous Connective Tissue.—**Contusions.**—Owing to the great elasticity of the skin, force applied to its surface by a blunt object may produce a solution of continuity of the structures beneath without separation of the skin itself. These, as well as crushing effects, may also lead to rupture of blood-vessels and hemorrhage into the subcutaneous connective tissue (hematoma). The presence of long elastic fibers in the subcutaneous connective tissue will account for this power of resistance to injury possessed by the skin.

The arrangement and extent of these fibers are not the same in all portions of the surface of the body, but tend to follow the direction of the muscles of a part. The fibers pursue a course almost parallel with the limb in the extremities; upon the trunk they are irregularly distributed as regards direction; while about the mouth and eyes they follow the course of the fibers of the orbicular muscles. In the patellar region and about the olecranon the elastic fibers pass in a concentric direction.

Wounds of the Skin.—The manner in which wounds of the skin will gape will depend upon the location of the wound and the direction in which it divides the elastic fibers. The maximum amount of gaping occurs when the wound is upon an extremity and passes at right angles to the direction of these fibers, and the minimum amount when it passes in the same direction as the elastic fibers, so that but few of the latter are divided. The proximity of the wound to one of the ginglymoid or hinge-like joints will likewise govern the amount of gaping. When in the neighborhood of the elbow- or knee-joint, tension upon the convex side of the articulation will tend to increase the separation of the wound-edges. In the sole of the foot and palm of the hand

the fibrous structure of the connective tissue is so arranged as to form a dense attachment between the papillary body and the underlying aponeurotic structures, and hence in these regions wounds gape but very slightly.

Abrasions.—In abrasions of the skin involving but little more than the papillary layer, the reparative process takes place readily and pathological inflammation does not occur. The injured layer of the rete Malpighii furnishes a few drops of blood and exudate, which, mingling together and undergoing coagulation, cling to the abraded surface Evaporation of the watery constituents leads to drying of the mass and a crust or scab is formed. The underlying wounded surface i thus protected; the mass itself in the dry state presents no longe a favorable pabulum for bacteria, and suppuration is prevented.

In this method of repair, known as *healing under the scab*, there i complete development of the epidermal layer beneath the incrustation if the latter is permitted to fall off of itself. It is only possible in natural way when there is but a slight amount of primary-woun secretions, and in situations favorable to rapid desiccation. More o less successful attempts to imitate the formation of the scab or crus by artificial means have been made in wounds extending into the sub cutaneous connective tissue and involving blood-vessels and lymph channels. Hermetical sealing of the wound by means of collodion c similar substances, asepsis having been previously assured and th wound-edges brought together, is often quite efficient. Any occlusiv method which prevents the entrance of extraneous matters and irrita ting substances imitates the process of healing under the scab.

Traumatic Inflammation of the Skin.—The skin may take on sup purative inflammation from infection originating in the skin. The in flammation, however, under these circumstances is superficial in cha acter and comparatively harmless, involving only the rete Malpigh and papillary layer. Rapidly-progressive suppurative inflammation the skin only, owing to the dense character of the parts involved, exceedingly rare and almost impossible.

Traumatic Inflammation of the Subcutaneous Connective Tissu —Phlegmonous inflammatory conditions of a very severe charact are easily produced in the subcutaneous connective tissue, owing the arrangement of the elastic fibers in this situation, and to the fa that the lymph-current runs in the same direction. Phlegmonous i flammation of the subcutaneous connective tissue, however, does n always have its origin in a palpable wound involving this structu Bacteria of sufficient infective power, which have gained entrance the rete Malpighii by an almost microscopic breach of surface, may the find sufficient pabulum for their maintenance so as to reach the subcu neous connective tissue finally. Here they propagate rapidly and produ their untoward effects. So-called idiopathic phlegmonous inflamm tions are to be accounted for in this manner. The more or less co stant coexistence of lymphangitis renders it probable that the infecti makes its way along the lymph-channels. *Traumatic erysipelas*, erysipelatous cellulitis, is said to be present where the papillary la and rete Malpighii are involved simultaneously with the subcutane connective tissue in the inflammatory process.

Loss of Substance.—This may occur in the skin either as the direct result of trauma, or indirectly from sloughing following the injury, and from the presence of a very high grade of phlegmonous inflammation as well. Destructive lesions of the skin likewise follow as an effect of extreme heat and cold (burn and frost-bite), and from ulceration.

In the repair which takes place the first essential is the proliferation of healthy granulations. By a process of contraction these subsequently approximate to some extent the margins of the granulating surface. In this way the defect is partially corrected by the neighboring tissues, but these in their turn are so displaced as to give rise in some situations to very serious deformities.

In order to complete the process of repair, in addition to the attempt at closure of the defect by cicatricial shrinkage, the formation of an epidermal layer is needed. This formation may take place rapidly or slowly. The resulting epidermal formation when completed may be a firm and solid layer, or it may be found to be thin and defective, with a tendency to break down in ulceration. Under these latter circumstances further aid may be needed. This aid is furnished by plastic procedures, skin-transplantation, etc. (Reverdin, Thiersch).

The Cicatrix.—The complete cicatrix is designed to serve the purposes of the normal structure which it replaces, although it is never identical with these either anatomically or functionally.

Recently-formed cicatricial tissue (Fig. 32) may break down and take on inflammatory conditions, particularly if aseptic precautions

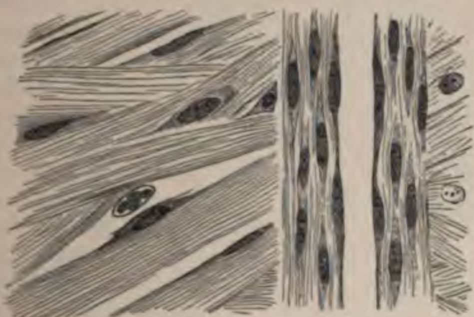


FIG. 32.—Cicatricial tissue; × 670.

have been neglected during the healing process. Abscesses may form in scar-tissue from the presence of bacteria, as well as foreign bodies, such as bone-spiculæ, or portions of ligature or suture-material. Ulcerative conditions in the recent cicatrix result from mechanical causes, such as friction from the clothing, and heal readily; later on, however, with lessening of the blood-supply, they heal but slowly.

Owing to the unyielding and inelastic character of the cicatrix, solutions of continuity at this site may occur more readily than in the soft and elastic normal structures. The presence of dense and extensive scar-tissue may give rise to pain along nerve-trunks, either from involvement of the nerve-sheath in the cicatrix, from simple pressure, or from tension consequent upon shrinking of the cicatrix.

Certain degenerative changes are observed to occur in scar-tissue, to which the term *cicatricial keloid* is given. This condition is characterized by increased density, and by deep reddening due to increased vascularity of the scar-tissue, together with growth into the surrounding tissues. Extirpation, followed by primary union and even skin-grafting or transplanting, does not prevent recurrence. Electrolysis, elastic pressure, and multiple scarifications are recommended, followed after twenty-four hours by the application of mercurial ointment twice daily, the scarifications being repeated until the growth disappears.

Degenerative changes of a malignant character are observed in old scar-tissue. This consideration does not include recurrences of malignant growths in operation-wounds following their extirpation. True cicatricial carcinomata are divided into two groups: (1) Those which have their origin in heretofore unchanged and typical cicatricial tissue; (2 those which occur in cicatricial tissue, the site of previously existing bu benign ulceration, such as ulcers, bone-fistulæ, old urinary fistulæ abou the penis, dysenteric and tu bercular intestinal ulceratior and parturient lacerations o the cervix uteri. They ma occur, also, upon the granu lating surface of cicatricial tis sue which has never been cov ered with normal epitheliun

FIG. 33.—Healing of tendon.

The disease may develo where tension is exercise upon a scar to overcome c reduce deformities due to tl latter. It tends to sprea upon the surface, and, sav in cases of extreme mali nancy, rarely passes into tl depths.

Tendon.—The mann of healing in divided te dons will vary according the presence or absence blood-clot, as well as a cording to the maintenan or non-maintenance of ase tic conditions. Usually su ficient hemorrhage occu from the separated ends fill the gap between with firm cylindrical clot. growth of new tissue tak place in the tendon-shea within the first few da which bridges over the spa between the retracted ends, and encloses the latter for some distan beyond the point of division (Fig. 33). This new tissue consists

spindle-shaped cells whose long axis is placed parallel to the tendon. It has its origin in the wall of the sheath, and not in the divided edges of the tendon itself. Absorption of the blood-clot is induced by lateral pressure of granulations, which form upon the borders of the clot and push their way into its interior. From the tenth to the fourteenth day a rich network of vessels forms in the new tissue communicating with the vessels in the cut surfaces of the divided tendon. An anastomosing network of vessels also forms in the granulations which surround the blood-clot. With the absorption of the clot the provisional new tissue disappears and its fusiform cells diminish in number, being replaced by another new tissue or intercellular substance which greatly resembles tendon-tissue.

When the tendon-ends are widely separated the tendon-cells take but little part in the repair, comparatively speaking. When the ends are approximated, as, for instance, in tendon-suture, the new tissue still more closely resembles tendon-tissue. Under these circumstances it is believed that the action of these cells is more pronounced in the regenerative process.

The process of repair in tendons therefore consists essentially of a connective-tissue proliferation originating in the connective-tissue coverings of the tendon, a portion of which stretches from one extremity to another after the division of the tendon proper. This becomes highly vascularized, and is then replaced by another new tissue which constitutes the definite splice that finally unites the divided ends.

Extravasation of blood from the divided vessels between the cut ends of the tendon is not essential. When it does not take place, the walls of the sheath come in contact and a band is formed, uniting the ends of the tendon. New tissue grows upon this band and between its walls, and the same result is attained as in the case of the interposition of a blood-clot. In fact, both excessive extravasation of blood and inflammatory effusion from infection may be highly disadvantageous to the reparative process.

Muscle.—In injuries to muscle its contractility plays an important part. Separation of the fibers in a transverse direction results in a gaping of the wound in proportion to the extent of the division.

Following a wound or rupture of a muscle the blood-vessels pour out a mass of blood which fills the gap between the injured muscular fibers. The connective tissue proliferates in the coagula, so that in a short time the latter are absorbed. With the absorption of the blood-clot, which, up to this time has served as a trellis-work for the support of the new vessels, there remains, as a result of the rapid connective-tissue proliferation, a mass which forms a swelling of exceptionally fine consistence, the so-called *muscle-callus*, or muscular cicatrix. Muscular fibers in the mean while are in process of production, and develop in this newly-formed tissue so as to replace the latter, provided that not more than an inch of space intervenes between the divided ends of the muscle. The basis or groundwork of the regenerative process is the fibrillæ in the muscle-fiber (Kölliker). In the case of non-striated muscular fiber the multiplication takes place by indirect or nuclear cell-division, or the process known as karyokinesis. In defects of

unstriped muscular fibers the regeneration takes place from the margins, the center being at first occupied by connective tissue.

In striated muscular fiber the first evidence of cell-proliferation in the regenerative process is found in the nuclei of the muscle-forming cells, or myoblasts, nearest the seat of the injury (Tizzoni). With the increase of these nuclei the new elements present more or less of the figures characteristic of the karyokinetic process (Levern). The more severely injured of the muscular fibers perish or undergo degenerative changes, and are removed by absorption within the first few days, the regenerative process being accomplished in those which remain striated (Klebs) (Fig. 34).

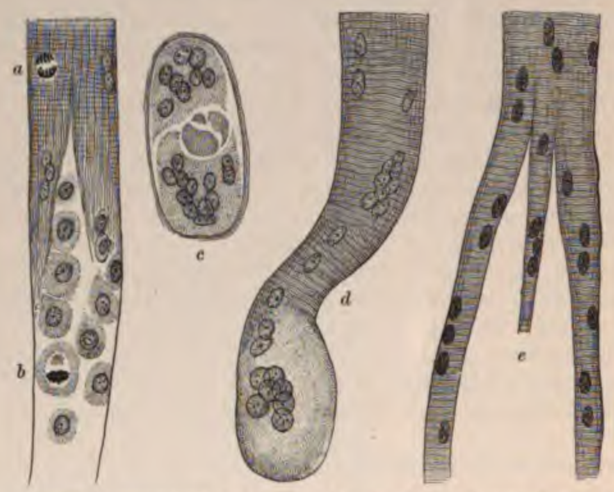


FIG. 34.—Repair of muscle (× 350): *a*, nuclei division (three days after rupture); *b*, mus cle-nuclei transformed into protoplasmic cells, one of them in the stage of mitotic division *c*, giant cell containing a necrotic muscle-fragment (from a muscle-scar of twenty-six days); muscle-fibers ending in protoplasma (from a muscle-scar of twenty-one days); *e*, dividing mu cle-fiber (from muscle-scar of forty-three days).

Certain preliminary and temporary changes are observed, the principal feature of whic is the development of granulation upon the basis of cell-division in the perimysium and i the endothelia of the small vessels. These granulations disappear, and active proliferatio of muscular cells occurs. These cells in their turn disappear (Nauwerck), and elongatic of the remaining fibers at the seat of injury takes place. Later on, the resulting prolong tions present club-shaped extremities richly supplied with nuclei. These muscular buds a the result of new-cell formation within the sarcolemma; they make their way through th delicate structure, appearing both at the divided ends and upon the sides of the fibers. Th are at first composed of protoplasm; later they become transformed into striated fibers. the newly-formed muscular fibers grow from opposite sides of the defect they invade t connective-tissue cicatrix, become thicker and cylindrical, and interlace (Neumann). T connective-tissue scar disappears more or less completely according to whether the defect be filled in is a large or a small one. In small wounds the defect may be filled entirely muscular tissue, while in large wounds there may be a bridging-over of the defect by co nective-tissue cicatrix in which there is only a small proportion of muscular tissue.

Nerve.—Following division of a nerve, the first change noticed a retraction of the sheath. Myelin is then spread over the divid ends, and the latter become united by a gray translucent tissue. Tl distance to which the cut ends finally retract governs the furth changes which occur. For several days the distance between the c ends increases, owing to the presence of some elastic fibers in the neu lemma. With the removal of a fourth of an inch of a nerve, or t separation of the ends by this distance, regeneration cannot take pla

unless the ends are brought together by artificial means. In the absence of approximation of the divided ends, the intervening space is filled by cellular granulation-tissue containing vessels. This, in time, forms a fibrous connecting cord, devoid of nerve-tissue, between the cut ends of the nerve. In the meantime the ends of the nerves undergo changes, which differ, however, in the two ends.

In the central end the fibers are comparatively but slightly affected (Glück). The myelin is rapidly reduced to fine granules, which, later on, assume a yellowish-brown color on treatment with osmic acid. The nuclei multiply, increase in size, and become flattened against the sheath of Schwann. An infiltration of leukocytes into the nerve-substance occurs. The axis-cylinder remains intact.

The changes in the peripheral end vary with the lapse of time following the infliction of the injury. In about fifteen days after the injury segmentation of the myelin occurs. The axis-cylinder is almost absent at this time. After thirty days but a very slight amount of myelin remains, and the axis-cylinder is no longer traceable, while the nuclei of the sheath are but slightly increased in number. At the end of three months it is no longer possible to recognize any nerve-tubules; the nerve-bundles are replaced by circular masses of tissue which have the appearance of connective tissue with many nuclei. These processes of degeneration may cease at a short distance from the divided end, or they may involve the whole periphery. They commence almost immediately after the injury, and continue until the nerve has undergone complete atrophy (Waller).

The central or upper end of the nerve becomes bulbous, particularly in stumps after amputation. These bulbous growths upon the end of the nerve-trunk were formerly supposed to be simply fibrous tissue; but it is now known that they contain nerve-elements as well, which replace the altered distal portion of the cut nerve (Hayem).

In severe cases of *contusion* of nerve the changes are similar to those which occur in division. In cases less severe there may be thickening of the neurilemma at the point of injury, caused by a collection of round and spindle-cells. This interferes with the processes of regeneration, and in the course of a few days the degenerative changes of Waller set in, in which both the medullary substance and the axis-cylinder are apparently implicated (Tillaux), and during which a temporary, although for the time being complete, paralysis occurs. In milder cases the axis-cylinder remains intact and degeneration does not occur (Erb).

This is well exemplified in the so-called "*Saturday-night paralysis*," in which, in the course of a debauch, the patient falls asleep in a chair with his arm hanging over its back in such a manner as to cause prolonged pressure upon the axillary nerves. Here there is a slight hemorrhage into the sheath, and a few fibers may be separated. A large proportion of the disturbances, however, are mechanical, and simply involve displacement of the semi-fluid contents of the tubules (Weir Mitchell).

Bone.—The reparative process in subcutaneous injuries to bone consists in, first, resorption of effused fluid and destroyed tissue, and second, the formation of callus.

Callus is formed principally by the periosteum and medullary tissue, the former playing the most important part in its production. The

torn periosteum becomes reunited and a ring of new-formation tissue develops at the site of the fracture, constituting the so-called *provisional callus* of Dupuytren. The provisional callus is formed by the innermost or osteogenetic layer of the periosteum (Ollier). During the first few days calcium salts are deposited between the ends of the fragments. While the provisional callus is undergoing the process of formation the medullary substance forms the *definite callus* of Cruveilhier. While the terms "provisional" and "definite" callus are still retained in descriptions of the reparative process in bone, yet they are not exact, for although the outer ring is formed earlier than the connecting dowel from the medullary substance, both alike contribute to the final or definite repair.

The Haversian canals likewise take part in the reparative process, as do also the cortical lamellæ, to some extent. The ossific process commences in the newly-formed tissue between the fragments. The latter, together with the new-formation tissue furnished by the periosteum and medullary structure, becomes solidified in a mass, with the result of complete formation of the callus. The reparative process in man occupies a length of time varying from three weeks to as many months.

With the completion of the reparative process there occurs a gradual restoration of the callus to the condition of true bone (Fig. 35)

FIG. 35.—Union of bone in rabbit. Three weeks.

This is known as *reformation of the callus* (Lossen), and occupies year or more. It consists of the production of systems of regul lamellæ and the replacing of the dowel which divided the medulla cavity of the bone into two portions, by true medullary substance. fractures involving the articular extremities of bones, the medulla callus is finally converted into true cancellous tissue. So closely do the reparative process follow the original formation that, in fractures the neck of the femur the reformed callus follows the lines best calc lated to bear the weight of the body, as in the normal state.

The histological process involved in the formation of callus and final regeneration to normal bone, consisting as it does of *cell-infiltr tion*, *new-formation of vessels*, and *condensation of newly-formed tiss* is analogous to processes of repair in soft parts when union by fi intention is obtained. The newly-formed tissue is the result of t proliferation of existing osteoblasts (Fig. 36). The traumatic irritati has reduced the bone to a condition analogous to or identical w young bone, as shown by the fact that very frequently cartilaginc

tissue is found in the newly-formed periosteal callus. The manner in which the newly-formed tissues appropriate the salts necessary for their proper construction is as yet unexplained.

A curious incident in connection with the formation of callus is the fact that, under the influence of irritation, as, for instance, that which occurs when extreme displacement or defective fixation of the fragments is present, the neighboring structures become the seat of deposits of callus. Tendinous, muscular, and synovial callus develops in this

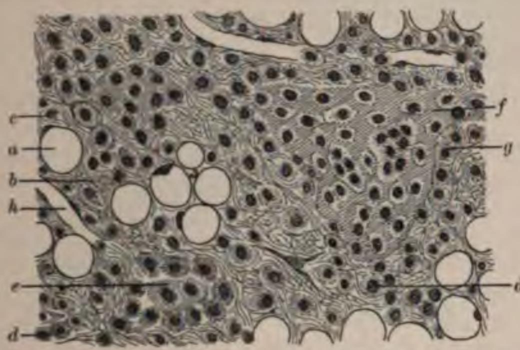


FIG. 36.—Myelogenous repair of bone (× 100). Specimen from the interior callus of a fracture of the fibula fourteen days old: *a*, fat-cells of the medulla; *b*, red marrow; *c*, disseminated osteoblasts; *d*, groups of osteoblasts; *e*, first formation of bone-substance; *f*, bone-fibers in stage of formation; *g*, layer of osteoblasts surrounding newly-formed bone-fibers; *h*, blood-vessel.

manner. These callus-masses take no part either in the temporary or permanent fixation of the fragments, and hence they are known as *superfluous callus.*

In like manner *excessive callus* may be formed. In this condition an amount of reparative material, considerably in excess of the requirements of repair, is developed at the site of fracture. Like superfluous callus, it results from mechanical irritation due to improper coaptation or insufficient fixation of the fragments. In the case of transverse fracture the excessive callus is formed principally from the osteogenetic layer of the periosteum. Under these circumstances the circumference of the bone may be two or three times greater than the normal. This is in part due to the displaced fragments, and in part to the demand for a larger mass of reparative material to bridge over the lateral surfaces. The latter is particularly the case in fractures of the lower extremities, where the callus assists in supporting the weight of the body upon the completion of the process of repair. In fractures with considerable longitudinal separation of the fragments the gap between the latter is filled by an excessive amount of callus which at first develops. In oblique fractures with overriding fragments the excessive callus is produced both by the medullary substance and by the periosteum.

Cartilage.—Owing to its non-vascular structure, as well as to absence of channels for plasma-circulation and the consequent limited nutritive supply, the reparative capacity of cartilage is very low. In Redfern's studies of experimental wounds in articular cartilage the wound was found to be unchanged after twenty-nine days in one

instance. In cases of incised wounds of cartilage experimentally made upon dogs by Geiss, when but slight traumatism was inflicted and aseptic conditions were maintained, it was found that the wounds refused to heal; while, on the other hand, wounds made in the presence of micro-organisms underwent rapid repair.

Following fracture of cartilage covered by perichondrium, *regressive changes* take place at the seat of injury, the broken ends undergoing fatty degeneration. The reparative process is initiated at a short distance from the line of separation (Fig. 37). *Vascularization* takes

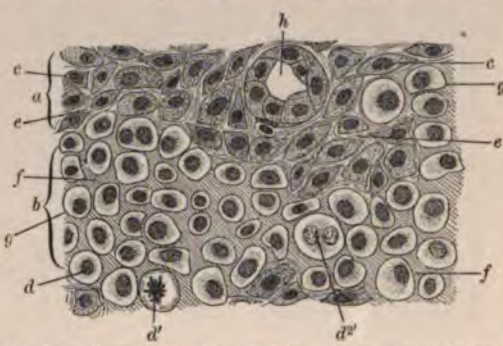


FIG. 37.—Repair of cartilage covered by perichondrium (× 100) (after Ziegler). Specimen after a fracture of five days: *a*, cellular plastic tissue; *b*, cartilage-tissue; *c*, proliferating cells from the perichondrium; *d*, cartilage-cells; *d'*, *d²'*, nuclear division of cartilage-cells; *e*, matrix of the plastic tissue; *f*, matrix of cartilage; *g*, capsule of cartilage-cells; *h*, proliferating endothelia of a blood-vessel.

place from the marginal vessels of the perichondrium, and a *connective-tissue proliferation* fills the space. The repair takes place almost exclusively through the perichondrium (Gussenbauer).

The tissue-proliferation resulting from the division and development of the cells of thi structure is followed by the formation of a fibrous cartilaginous tissue which undergoe changes toward *ossification*. It is highly probable that the cartilage-cells take but little, i any, part in the reparative process, although Reitz thought he had traced the formation o connective tissue from cartilage-cells, the latter being first transformed into spindle-cells, an then into connective tissue. His experiments were made upon the cartilage of the trache of the rabbit, while Redfern's were made upon articular cartilage; it was to this that Reit attributed the discrepancy in the results. Doerner's studies upon the manner of repair o incised wounds, as well as more complicated injuries of cartilage, confirmed the observatior of Redfern and Gussenbauer that the perichondrium is invariably found to take the mo active part in the process of healing.

In case of injury to, or loss of substance of, the cartilage of joint which is not furnished with perichondrium, a fibrous connective-tissu cicatrix develops, which in the course of time is changed into hyalin cartilage-tissue (Tizzoni). On the other hand, it is believed that de fects of joint-cartilage arising from a trauma undergo only partial repai the cartilage-cells possessing but low vegetative power. Whatev tissue-proliferation occurs is transformed into connective tissue.

When portions of joint-cartilage have been completely separate they do not become reattached to the joint-surfaces either at th original point of attachment or elsewhere. They either become *fr floating bodies* in the joint, or are encapsulated or attached by a ne connective-tissue covering which springs from the inner surface of th capsule.

Arteries.—The blood-vessels are composed of unstriped muscular fibers, elastic tissue, connective tissue, and endothelium. It has been customary to distinguish three coats, and to designate these, according to their location, as the internal, or intima; the middle, or media; and the external, or adventitia.

The *intima* is a delicate, elastic, and transparent membrane, composed, in the case of the larger arteries, of a layer of flat endothelial cells, a delicate layer of longitudinally-arranged connective tissue, and elastic tissue. The endothelial cells are irregularly polygonal in shape and have an oval nucleus. Sometimes the outer surface of the basement-membrane of the intima is covered by a layer of polyhedral cells, the so-called epithelioid cells (Czerny). In larger arteries there is an additional connective-tissue membrane, which in the adult is distinctly fibrillated (the striated internal coat of Kölliker).

The *media* is composed of unstriped muscular fibers, elastic and connective tissues. In small and medium-sized vessels the proportionate amount of muscular tissue is greatest, while in larger arterial trunks the elastic tissue preponderates. The muscular fibers are of the smooth nucleated variety, and are arranged in a circular manner. In the larger vessels there is a longitudinal muscular layer as well (Bardeleben). While the circular direction of the muscular fibers is maintained in a general way, in addition to the longitudinal layer just mentioned, there are some which have an oblique direction. These prevent complete separation of the middle coat when a round ligature is tightly applied to the vessel. The elastic tissue of the middle coat is disposed in three layers. One is imposed between this coat and the intima, another is connected with the external coat, while a third is arranged so as to fill the interspaces between the muscular layers which lie between the two elastic layers already described. The elastic fibers correspond in direction to the muscular fibers. It was formerly the general belief that the middle coat of an artery was not regenerated or reproduced when injured or destroyed, but that only a reparative process occurred, which took place by the formation of a simple connective-tissue cicatrix. This view is opposed by Warren (*vide infra*).

The *adventitia*, or external coat, is composed of closely-woven bundles of connective tissue, together with more or less elastic tissue arranged in layers. The principal function of the external coat is to serve as a support for the nutrient vessels of the arterial wall itself (the vasa vasorum), which rarely spring from the vessel that they supply, but are derived from neighboring arterioles (Flint).

The processes of repair in blood-vessels have been studied more or less completely by almost every experimental pathologist since the days of John Hunter, who first enunciated the theory of the organization of the thrombus as a necessary part of the reparative process. The history of the study of the behavior of vessels after injury is the history of the evolution of the theory of cell-action and the part which it plays in the building up of new-formation tissue in all the structures of the body, since, in the injured vessel, can be studied the action of the colorless blood-corpuscles, the wandering cells, the fixed connective-tissue corpuscles, and the endothelium.

Contusions produce more or less tearing of the smaller vessels, both arteries and veins, in the subcutaneous connective tissue. As the blood escapes into the meshes of the latter, it coagulates and forms what is known as a hematoma.

Contusion of an artery is sometimes occasioned by a bullet or other missile striking it and glancing off. The injury to the tissue of the vessel may be so great as to cause final rupture of the vessel. In other cases the supposed contusion proves to be really a partial rupture of the artery, a portion of the intima giving way and curling up so as to cause occlusion more or less permanent at this point.

When the trunk of a large artery is wounded, in addition to the blood which escapes from the interior of the vessel, there is a hemorrhage from the wounded nutrient vessels which are severed in the adventitia. The blood from this wound in the vessel-wall coagulates, arresting the bleeding. The coagulum thus formed extends in the interior for varying distances. Under these circumstances, unless there is an external wound, a large and tense hematoma is found outside the vessel. This hematoma, together with the coagulum in the wound in the vessel-wall, as well as that portion of it which extends within the vessel, usually forms one solid mass of blood-clot. The process of repair now begins. Absorption of the blood-clot occurs, and as this proceeds that portion of the mass which sealed the wound in the vessel-wall is replaced by glandular tissue. Finally a cicatrix of connective-tissue origin replaces the normal structure. This forms a weak point which, when subjected to arterial pressure, is gradually forced in an outward direction until an aneurysmal sac is formed.

When an artery is completely severed, subjected to torsion, or ligated, permanent obliteration of the vessel usually follows, either through natural or artificial means. This takes place by the formation of an intravascular cicatrix. The basis of the reparative process is a thrombus within the vessel itself. This, however, only plays a passive rôle, the repair proper being invariably effected by cell-proliferation from the vessel-wall. This is in opposition to the view formerly held, that the thrombus became vascular either from the nutrient vessels of the adventitia or from the lumen of the vessel itself, and that the intravascular cicatrix was built up from the histological elements of the thrombus. One of the most potent arguments against this doctrine is the fact that coagulation of the blood occasionally fails to take place, and that primary union of the inner wall occurs without the formation of a thrombus. Further, there is no more reason to expect that the morphological elements of a thrombus will initiate and carry on tissue-proliferation than that they will produce blood-extravasations elsewhere. On the contrary, it is a generally recognized fact that these latter invariably undergo retrograde metamorphosis.

When an artery is tightly constricted or subjected to torsion, the current of blood is permanently arrested. The innermost coat, and to some extent the middle coat, gives way. The adventitia, or outermost coat remains intact, and, in case of ligature, is constricted into a narrow circle. The internal and middle coats, mainly from their elasticity retract and curve upon themselves, as division takes place. Two

thrombi form, one above and the other below the point of constriction. The former is usually the larger of the two.

It was formerly supposed that the mere arrest of the blood at the point of obstruction was sufficient to cause its coagulation. Alex. Schmidt has shown, however, that a third body, having its origin in the so-called blood-plaques, the disintegration of which gives rise to a ferment, is necessary. The coats of the artery being ruptured, the disintegration of the cells containing the fibrin-ferment is initiated, and fibrin is deposited upon the recurved tunics. In the event of failure of coagulation, the two opposing surfaces may cohere by multiplication of the endothelial cells (Riedel). When the clot is formed, which may occur in an hour and is rarely delayed beyond six hours, it not infrequently passes into the collateral branches (Ballance and Edmunds). Coagulation takes place likewise when the tunics are injured sufficiently to prevent the blood-current from continuing its course (Michael Foster). A profound alteration of the nutrition now takes place. The vasa vasorum become blocked and a plastic effusion ensues. The loop of the ligature is buried in the effusion. The opposed endothelial surfaces proliferate and adhesions form between them. This effusion occurs more rapidly when the coats are ruptured. In the course of the first two days granulation-tissue forms about the point of ligature, as well as for some distance above and below the point of the latter. The inflammatory product varies in amount, being governed by the grade of the traumatism inflicted, as well as by the presence or absence of sepsis. As a result of cell-proliferation a callus is formed, which protects the vessel from the dangers of hemorrhage. An apparent ampullation of the vessel occurs immediately above the clot (Bryant). This enlargement, however, is more apparent than real, and, in reality, depends upon a contraction of the vessel above the clot (Warren).

The function of the clot is threefold: First, it acts as a cushion against which the impulse of the blood is received, and in this manner prevents disturbance of the plastic process; second, it forms a trellis-work support to invasion and proliferation of cells as they advance from side to side of the internal coat of the arterial tube; third, it furnishes nutriment to these cells.

If repair progresses favorably the granulation-tissue penetrates deeply into the thrombi, and also exercises a solvent action upon the bundles of fibers surrounded by the ligature. The process of healing from this point resembles the repair of fractures. The new-formation material within the vessel is comparable to the internal, and that outside the vessel to the external, callus of a fracture (Warren) (Fig. 38). These structures are of a provisional character. Upon their disappearance it is found that a growth has taken place in the intima which forms a permanent cicatrix. According to Warren, this cicatrix represents a reproduction of the three walls of the vessel. Its innermost layer is composed of endothelium, its outermost layer is a connective-tissue formation from the adventitia, and between these there is found a layer of muscular cells developed from the middle coat of the vessel. With the absorption of the provisional tissue and the complete formation of the definite cicatrix, the latter acts as a connecting cord between the two ends of the vessels (Fig. 39). A small central vessel penetrates

the cicatrix. This replaces the network of vessels which supplied the provisional tissue and disappeared with the latter. It passes from the lumen and anastomoses with the system of capillaries which surround the stump of the obliterated artery.

A ligature applied to a blood-vessel is always treated as a foreign body by the tissues, and an attempt is at once made by the cells to absorb it. The success of this attempt will depend upon the nature of the ligature-material. Gold- or platinum-wire ligature remains permanently in an unchanged condition. Lead, silver, iron, and other metals disappear by absorption sooner or later. All animal and vegetable ligatures are disintegrated and absorbed in time, varying with the character of the ligature-material and the method of its preparation. If there is any delay in the absorption, encapsulation occurs from the formation of connective tissue The absorption, however is not arrested on this account, but goes on, although slowly, to completion. As absorptior takes place the ligature material is replaced by new connective tissue In the case of anima ligatures the softenin and absorption of th ligature occur earlier i suppuration takes plac With the arrest of th blood-current at the sea of ligature the flow o blood is at once directed with increased pressure toward the lat eral branches which are given off nearest to the point of obstruc tion. These lateral branches communicate with arteries from th arterial trunk beyond the obstruction. In this manner the bloo finally reaches its original destination. This anastomotic or collater

FIG. 38.—Carotid artery of horse two weeks after ligature. Callus-formation (Warren).

FIG. 39.—Carotid artery of horse three months after ligature. Partial absorption of callus.

circulation is usually restored at once, and forms for itself more or less wide channels for carrying on the circulation. The combined area of these collateral branches equals that of the trunk which has been obstructed. In exceptional instances in which diseased conditions of the arteries exist, or where infiltration of the surrounding tissues prevents a prompt enlargement of the anastomosing branches, the blood-supply to the periphery is retarded or entirely prevented (see Gangrene).

Glands.—The repair which takes place in glandular structures is accomplished by a regeneration of the gland-substance. In the case of partial excision of a gland, as, for instance, in the testicle, there is an increase of the essential anatomical structure, the tubuli seminiferi, during the healing process (Griffin). In experiments upon dogs, Tizzoni observed production of new hepatic tissue in wounds of the liver as healing took place. In the case of the spleen, even in complete extirpation of this organ, there is a very effective effort made toward the restoration of function by the production of new gland-tissue from the blood-vessels of the neighboring peritoneum. Tissue-proliferation takes place in the adjacent vessels, the product of which corresponds to normal splenic tissue, both in its anatomical characteristics and its physiological properties. The newly-formed gland-tissue occurs as isolated nodules which develop around new offshoots from the vessels of the peritoneum about the site of the hilus, which, appearing in the beginning as new connective tissue, is finally supplied with follicles, pulp, and a proper arrangement of blood-vessels. That these possess the function of the original spleen is shown by the fact that the blood-corpuscles, which had been diminished following the extirpation of the organ, increase in number as the new splenic tissue is produced (Tizzoni and Fileti). Nor does it seem essential that the entire spleen should be removed in order that production of new spleen-tissue should occur from the vessels of the peritoneum. The excision of a portion of the organ is followed by the formation of new spleen-tissue upon the omentum in the neighborhood, entirely independently of tissue-proliferation in the wound in the spleen itself.

In a similar manner, it is claimed, new lymphatic tissue is rapidly produced after partial or complete removal of a lymphatic gland, the vessels of the adjoining adipose tissue serving the same purpose as those of the peritoneum in the production of splenic tissue (Baier and Bacialli). It is more than probable, however, that the new gland-tissue is the product of tissue-proliferation from the divided ends of lymphatic vessels.

CHAPTER VI.

CONSTITUTIONAL REACTIONS TO WOUNDS AND THEIR INFECTIONS.

ASEPTIC WOUND FEVER; SAPREMIA; SEPTIC INTOXICATION; SEPTICEMIA; PYEMIA; SEPTICOPYEMIA.

When local injuries have been inflicted upon the animal body, a constitutional reaction is prone to follow—a reaction in which are associated elevation of the body-temperature, and cardiovascular, respiratory, and nervous phenomena which we designate under the clinical term fever. It is not within our province to discuss the essential nature of the fever, but only to consider its relationship to surgical conditions. Neither is it our purpose to dwell upon that hyperthermia which occurs after the passing of the catheter or sound, when unassociated with infection or renal lesions, and which, as it is a simple vasomotor disturbance, is better referred to another classification than that of fever (Kraus).

The common pathological element in all forms of fever is intoxication. The poisons which bring about the fever are of different origins, and gain entrance to the circulation in a variety of ways.

AUTO-INTOXICATION.

Auto-intoxication is an expression of recent origin, used to designate that form of self-poisoning in which neither wound nor gross pathological lesion exists, but in which poisons elaborated within the body are not excreted with proper activity, so that the system at large is injured. While auto-intoxication is, therefore, not dependent upon any form of wound-complication, a slight knowledge of it is nevertheless so important for our study of wound-infection that we will very briefly refer to it.

A simple and familiar kind of auto-intoxication is that in which the bowels do not empty themselves freely enough, so that the products of putrefaction from the intestine and excrementitious matters from the liver and the intestinal mucosa are not cast out promptly, but remain long enough in the body to be partly resorbed. The skin, the lungs, the kidneys, the liver, and the intestines are the most important excretory organs. Interference with the activity of any one of them may result in the retention of poisons which cause a great variety of functional disturbances depending for their peculiarities upon the properties of the retained chemical bodies. The greatest activity is now being manifested by scientific men in this complex and difficult field, and many chemical compounds have been isolated from the

excreta, their chemical formulæ ascertained, and their physiological properties determined.

Auto-intoxication is of especial importance to the surgeon, because the traumatic infectious organisms find the tissues of an animal depressed by the resorption of excrementitious principles much more vulnerable than those of a normal individual. All experienced surgeons realize the very great importance of having the bowels in a good state of activity at the time of performing operations. Not only this, but many insist that the intestines be as nearly empty as possible, and that the so-called intestinal antiseptics be given beforehand, since the loss of even a moderate amount of blood, and especially the frequent inability to retain water in the stomach, make resorption of fluids from the intestines, which always contain more or less noxious matter in solution, especially likely to occur. This danger may be partly averted by injecting into the rectum 4 to 8 ounces of sterilized water every three to six hours after the operation, until abundant urinary secretion tells us the blood-volume is made up and that excretion, by that important avenue at least, is going on well. For the same reason patients should not, as a rule, be denied abundance of drinking water, after post-operative vomiting has ceased, unless some especial indication exist for denying it.

To prevent the ill effects of excessive auto-intoxication, one must be especially upon his guard in certain progressive organic diseases in which surgical operations are often required.

For example, in diabetes we are cautioned to defer amputation for gangrene, if possible, until the glycosuria is reduced to as low a point as possible; and in the various renal maladies operations of election are deferred until the function of urinary excretion is performed with maximum activity. It is important to interrogate the condition of the kidneys and of the heart, upon which renal activity so much depends, before undertaking surgical procedures which, by throwing additional burdens on the eliminating organs, may cause an auto-intoxication which, if not dangerous in itself, may become so by favoring local or general infection.

The **diagnosis** of auto-intoxications must be made, partly by a reference to the positive symptoms associated with the partial functional failure of the different organs, partly by the exclusion of various forms of intoxication of a more strictly surgical character yet to be discussed. The commonly prompt occurrence of furred tongue, a bitter taste in the mouth, headache, anorexia, and malaise with a slight rise of fever after failure of defecation for twenty-four or forty-eight hours, suggests the need of laxatives. Persistent headache, a tense small radial, a hypertrophied left ventricle, mental wandering or delirium, twitching of the limbs or of muscle-groups together with more direct evidences, call attention to renal insufficiency. For the refinements of diagnosis in this department the reader must seek the works on internal medicine.

The **treatment** of auto-intoxications by medieval and even comparatively modern practitioners was largely by phlebotomy. This was not wholly without propriety, since the removal of a comparatively small quantity of blood and its substitution by water insure the immediate removal from the body of a quantity of concentrated poisonous matter which it would require a vastly larger amount of urine and

very much more time to carry away. Practically, however, we now reach the same result by using laxatives, diuretics, and sudorific remedies.

ASEPTIC WOUND FEVER.

Aseptic wound fever is an expression used by Volkmann to indicate the systemic reaction taking place in the bodies of those in whom wounds are healing without the interference of infection—as, for example, in simple fractures.

Gussenbauer has called attention to the illogical character of the expression, since a term indicating the mere absence of a pathological characteristic should not serve to denote a morbid entity. Other names are sometimes used. *Ferment fever* was an expression suggested by Bergmann under the misconception that the fibrin-ferment of effused or disintegrated blood was the active agent in producing the fever. *Resorption fever*, *after-fever* (Billroth), and *simple traumatic fever* are other more or less convenient or suggestive additions to the terminology.

Etiology.—The cause of this form of transitory fever coming on a few hours after injury was sought by many earlier observers in the liberation and resorption of fibrin-ferment from the blood. It was observed that after transfusions of blood, in which many millions of red corpuscles are destroyed, and when tissues were suddenly killed by traumatism, a rise in temperature occurred even in the absence of infection. The same thing was seen to occur even when inert substances like charcoal were introduced into the veins. It was supposed that these substances brought about destruction of some blood-corpuscles, and that thus the fibrin-ferment was set free.

Schnitzler and Ewald, working in Albert's clinic in Vienna, have recently studied anew the fever-producing chemical bodies indisputably set free in subcutaneous hemorrhages. While asserting that the older notions of the chemistry of fibrin-ferment must be so modified as to agree with the results of modern research, and that the fibrin-ferment cannot any longer be regarded as the active fever-producing body in effused blood, they endeavored to isolate from such blood those chemical bodies which produce the symptoms of aseptic wound fever. They claim to have found two series of compounds exactly meeting these requirements—the nucleins and the albumoses. Both these substances are found in effused aseptic blood; both substances when injected into the bodies of healthy animals bring about a febrile reaction. Besides this, nucleins are known to be present in some of the supposedly inert substance (*e. g.*, wheat flour) formerly injected experimentally into the blood of animals to produce this febrile disturbance.

The exact **conditions** under which this kind of fever is produced are not as yet determined. Certainly there are many cases of extensive extravasation of blood that are followed by but slight reaction. The converse of the proposition is equally true, that often very small injuries are followed by great reaction. Doubtless the activity of the emunctory organs at the time of injury constitutes an important factor Some maintain that the pressure to which the effused blood is subjected is a favoring moment. The resorptive powers of the tissue that are in contact with the blood are significant.

After operations, this form of fever is most likely to follow when hemostasis has not been perfect, when drainage has been omitted, or when manipulation of a great amount of tissue has been prolonged and severe. Tillmanns considers the use of antiseptics in the wound an important causative element, since these chemicals destroy quantities of tissue-cells and predispose to post-operative oozing of blood.

The **symptoms** of primary or aseptic wound fever are simple an

not numerous. A few hours after a trauma, operative or accidental, the temperature rises to 100°, 101°, or even 102° F., rarely higher. The rise of temperature being gradual, and the degree attained not high, a rigor does not, as a rule, occur. The pulse increases in frequency in correspondence with the fever. The face may be slightly flushed and the tongue dry. The eyes are bright, and the patient makes but little complaint except to beg for water. These symptoms are of very transitory character. In a few hours, or within two days, the reaction is over, and henceforth the temperature remains normal throughout the course of healing.

The **diagnosis,** in the presence of these somewhat vague and uncharacteristic symptoms, must rest chiefly on a careful exclusion of other fever-producing conditions in the wound, and particularly upon the exclusion of inflammations in other parts of the body (pneumonia, bronchitis, nephritis). Since the prompt termination of the febrile movement is a most typical element in the symptomatology, the clinical observer anxiously watches for the defervescence to enable him to exclude the more dreaded wound-complications. In practice, we give but little anxiety to a moderate rise of temperature during the first twenty-four hours after traumatism.

The **treatment** of this form of wound-reaction is, in operative surgery chiefly, and most properly, prophylactic. The proper preparation of the patient, diminution of traumatism, abstinence from the use of chemical antiseptics, and curtailment of exposure to air are important points. Laxatives after operations are often used. Enemata of warm water, to be retained and resorbed, aid in elimination of the poisons. In laparotomies for non-infectious lesions it is common and good practice to leave in the abdomen a quantity of sterilized water, the absorption of which increases diuresis and diaphoresis.

SAPREMIA.

The fevers thus far discussed have been regarded as due to the resorption of toxins not elaborated by the action of bacteria, if we except the case of auto-infection from putrefaction. We have now to consider the systemic consequences of the invasion of wounds and wound-products by micro-organisms.

All bacteria produce their specific effects through the action of their excreta, or by virtue of the injurious action of certain chemical compounds existent in their bodies. The variety of these chemical compounds is very great. Many bacteria excrete products peculiar to themselves—chemical bodies often of definite composition and of well-characterized physiological properties.

When saprophytes grow upon or within the body under such conditions that their poisonous products are absorbed into the system, we speak of the complexus of resulting symptoms as *sapremia*. Clinically it is most difficult to separate cases of pure sapremia from cases of suppuration and septicemia. Besides this, mixed infections are especially likely to occur under those conditions in which putrefaction occurs. Nevertheless, there are a few *classical forms* of sapremia which can be fairly well recognized clinically. After childbirth, for example, the

uterus may be regarded as a wounded viscus. The placental site is the wound-surface proper, which can freely absorb poisonous matter from the uterine cavity. If, now, a portion of the placenta or of the fetal membranes is not expelled, and chances to become infected with germs of putrefaction introduced through the vagina, the conditions for the growth of the saprophytes are well-nigh ideal. Resorption takes place with great freedom. Large quantities of noxious matter are very rapidly introduced into the system at large and produce symptoms of poisoning. If the poisons are not of sufficient quantity or of proper kind to cause rapid death from toxemia (and this termination is uncommon), the offending mass of dead tissue may be removed by the attendant's art, with immediate cessation of the symptoms. A patient suffering from strangulated hernia encounters the risks of sapremia from multiplication of intestinal saprophytes in the strangulated tissues, although the action of the more aggressive attendant micro-organisms is often much more portentous. It is possible, also, for the blood-clots and wound-secretions of any open wound to putrefy and produce a condition analogous to that of intra-uterine putrefaction.

The poisons in action are of varied composition and of unequal toxicity. Many of the ptomaïns of putrefaction have already been isolated and experimentally studied.

The **symptoms** vary with the quantity of dead tissues to be acted upon, the peculiarities of the infecting micro-organism, and the rapidity of resorption. We may say, in a word, that the symptom-complex is that of progressive poisoning by nerve-depressing and fever-exciting agents. A chill, of course, occurs in those cases in which the temperature rises to 102° or 104° F., as is often the case. This chill, which is frequently the first sign of grave disturbance, is usually preceded by a slight rise in temperature, malaise, headache, anorexia, and a coated, dry tongue. The pulse grows more frequent and soft as the temperature rises. Vomiting, diarrhea, scanty, high-colored urine, and headache are succeeded, as the poisoning deepens, by restlessness, delirium, jactitation, and cold perspiration. At last, as death approaches, the pulse grows weaker, involuntary passages of urine and feces occur, and delirium is replaced by coma.

Should the amount of culture-medium be quite limited (blood-clot placenta, or other devitalized tissue), the microbes may exhaust their supply of pabulum, and the patient may recover without more ado But, clinically, the pus-microbes are so commonly in association with the saprophytes that usually only a gradual, instead of a sudden, regression of symptoms occurs, with a residuum of suppuration, requiring a greater or less amount of time to disappear. Typical, sudden and gratifying, however, is the recovery when, in one of the unusual cases of typical saprophytic toxemia, the putrefying placenta is extracted from the uterine cavity. The temperature falls within a few hours and all other outward signs rapidly disappear.

The **prognosis** of sapremia, then, depends upon the exhaustion of the culture-medium or its mechanical removal. Uncomplicated cases usually recover; but it is possible for the system to be overpowered in a few hours by the ptomaïns of putrefaction rapidly poured into the blood.

So unusual are these purely sapremic cases, and so difficult is it to exclude clinically the noxious presence of other bacteria, that some writers (Kocher and Tavel) would discard the term sapremia from our nosology. The diagnosis must be based upon the symptoms mentioned coming on a few hours or days after a trauma, with the added consideration of the local findings. The wound in such cases will present some evidences (redness, swelling, heat, pain) of inflammation and a discharge of thin acrid serous or serosanguinolent fluid from the wound. The discharge is usually malodorous; but it must be borne in mind that well marked cases of toxemia and sapremia may be induced by the growth of microbes which do not elaborate putrid products. A sour or rotten odor will usually be noted, however, and foul-smelling gases may be given off.

The **treatment** is first, of course, prophylactic; careful antisepsis or asepsis will always prevent this wound-complication in wounds made by the surgeon. Once the condition is established, it may usually be cut short by removing culture-matter, establishing drainage, and frequently irrigating the wound with a suitable antiseptic solution.

SEPTIC INTOXICATION.

Closely related to sapremia (which we have described as a toxemia of saprophytic origin) is *septic intoxication*, a disease due to the resorption of poisons from foci of suppuration. That the by-products of the pus-microbes cause profound local systemic disturbances, when injected into the healthy animal body, was proved long ago by direct experimentation.

Leber, as long ago as 1879, in studying aspergillus keratitis, reached the conclusion that the micro-organism must produce some soluble chemical bodies which, by diffusion through the tissues of the cornea, brought about the widespread inflammation noted. At a later date also (1888) he published an account of a crystalline pyogenic body, which he called phlogosin, derived from pure cultures of pus-microbes. Other observers have found that the cells of many bacteria contain proteids capable of causing non-progressive (aseptic) suppuration and of seriously affecting the general system when injected into cellular tissue.

The resorption of toxic chemical bodies from foci of localized suppuration is dependent upon a variety of conditions. *Granulation-tissue* does not readily absorb chemical bodies, since, as Billroth long ago pointed out, the granulation-tissue closes up the lymphatic spaces. The destruction of this granulation-tissue barrier is sometimes followed by a rapid rise of temperature. *Pressure within an* unopened *abscess* is responsible for almost all the resorption. The pus-poisons are resorbed readily even by granulations when under pressure. Drainage of abscess-cavities has for its object the removal of this pressure; if it were not so, the fever would remain high even after drainage is established, since the wound-surface continues to be bathed in pus. This is proved by the fact that the temperature rapidly rises when pressure is re-established in the abscess-cavity by plugging the drainage-opening. Often a patient suffering from abscess-formation has a higher temperature for a few hours after the opening of the abscess than he had when the pressure was at its height. This is due to the opening of lymph-spaces to resorption, by the surgeon's incision. Pressure has

another effect on the process of septic intoxication—that of favoring the spread of the infection into remote tissues, thus increasing at once the absorbing area and the amount of the poisons capable of being resorbed.

Not only are the toxic substances elaborated by pyogenic organisms capable of producing temperature-elevation, but the bodies of the bacteria themselves are equally poisonous. The bacteria destroyed in the contest with the tissues therefore add to the septic intoxication.

We speak clinically of intoxication when we have to deal with a systemic poisoning of pyogenic origin, in which there is reason to believe bacteria from the infected site have not found their way to distant seats or into the circulating blood itself. We feel especial confidence in such a **diagnosis** after we have excluded the possibility of septicemia by affording drainage to the abscess and after we have found that all evidences of toxemia are thus caused to disappear.

The degree of intoxication does not depend in given cases of septic poisoning upon the *quantity of pus* present. A small amount of pus, even a drop or two, under the periosteum, for example, may cause more violent symptoms than a half-pint under the looser parts of the skin. The toxicity also depends on the character of the cultures from which the inoculation was made. Infections from exceptionally virulent cultures give rise to much greater disturbance than those from weaker growths of the same bacterium. No doubt the lymphatic apparatus reacts to the toxins of pyogenic bacteria somewhat as it does to the bacteria themselves, as will be presently described (Halban).

The **clinical course** of septic intoxication is the clinical course of the systemic reaction in local suppuration. A furuncle will often discharge into the blood quantities of toxins sufficient to create great systemic disturbance. The temperature gradually rises with the growth of the inflammatory focus, so that often in a few hours it reaches 104° or 105° F. Should a large quantity of the toxins be suddenly thrown into the circulation—*i. e.*, when the inflammation is rapidly progressive and virulent, or when an abscess bursts into an actively resorptive cavity—the intoxication will be evidenced by a chill preceding the rise of temperature. In moderate intoxications the fever-curve is fairly regular, being lower in the morning than in the evening, as a rule. The elevation continues until the entire quantity of resorbable material has been removed, as may be the case with small and peculiarly conditioned foci, or until the progressive spread of the inflammation with the usual necrosis and liquefaction of tissues in the line of least resistance permits the escape of the pus. If large quantities of pus-toxins are thrown rapidly into the circulation, death may result from the sudden violent depression of the vital powers.

Septic intoxication must be clinically differentiated from septicemia according to rules formulated under the heading Septicemia. In all forms of pyogenic temperature-elevation a septic intoxication is present but we must exclude septicemia before limiting our diagnosis to septic intoxication alone.

SEPTICEMIA, PYEMIA, AND SEPTICOPYEMIA.

By *septicemia* we mean that form of systemic poisoning in which living bacteria enter the blood. It is necessary that the microbes reproduce themselves in the blood, and that they be found alive in that fluid, capable of growth when planted upon suitable media. We exclude by common consent those infections which are not typically pyogenic in character (anthrax, glanders, etc.). Septicemia is therefore not necessarily associated with putrefaction.

Pyemia no longer means, as its etymology implies, pus in the blood. By pyemia we now mean a form of blood-poisoning by pyogenic organisms, in which living bacteria are transported by the blood-currents to distant tissues, where they grow and produce abscesses; so that in pyemia the production of multiple abscesses is the typical pathological change, just as in septicemia the dominant feature is the systemic intoxication with the living bacteria in the blood.

Septicopyemia is a clinical term used to convey the impression that the symptoms of sepsis are marked as well as those of pyemia.

At the present time, therefore, we do not draw a sharp line between these three forms of pyogenic disease. Neither theory nor practice would now justify such a distinction, since, as the pathogenic organisms are the same in each of these conditions, the morbid anatomical changes vary more in degree than in kind, and the clinical signs do not enable us to distinguish unerringly between them. This inability to separate these forms of one disease has been delayed in recognition because in some of the lower animals typical septicemias are found—*i. e.*, the same bacterium injected into the blood always produces the same form of septicemic disease. In man the pyogenic microbes not only produce septicemia and pyemia, but also local infections whose manifestations are often entirely distinct from any systemic disease except a transitory intoxication. We have in man, then, no specific micro-organism of septicemia and of pyemia. The clinical pictures of these diseases are often obscured by primary local disturbances which may even prevent the unwary practitioner from recognizing the systemic invasion.

While it is true that man's septicemia is not a typical disease, many lessons and suggestions may be gained by a study of the typical septicemias of lower animals.

The classical research in this department of investigation is that of Koch on *mouse septicemia* (1876), who found that by injecting blood, which had been allowed to putrefy for two or three days, into the cellular tissue of house-mice, a mortal disease was produced, even when only five drops of the fluid were injected. Various forms of bacteria were found in the cellular tissues of the back where the injection had been made. The organs of the dead animals were found normal in appearance, and this fact, taken in conjunction with the fact that the mouse lived only four or five hours, led Koch to think the cause of death was toxemia and not septicemia. He then injected another series of mice with smaller doses—one to two drops. The majority of the infected animals lived; but a few died in about twenty-four hours. The latter at first developed a conjunctivitis; then the movements of the animal became more slow, the back became arched, and the extremities drawn up. Anorexia set in, respiration became very slow, and vital depression ended in death. The same effect was obtained with one-tenth of a drop of the liquid, death occurring forty or fifty hours after the injection. After death the animal remained in the same position. At the autopsy the organs appeared normal, but the spleen seemed a little enlarged. If now one-tenth of a drop of blood from the dead mouse was used to inoculate a healthy animal, the same disease developed and the mouse died in fifty hours. In his first publication on

this subject, Koch reported 54 mice successively inoculated with the septicemia; so that no doubt could be entertained in regard to the bacterial character of the disease or its deadly activity. The bacteria were seen with difficulty, until Abbe's condenser and good one-twelfth-inch objectives were used. They were found to be minute bacilli. The bacteria were proved to exist and to thrive in the blood, since the blood always showed the bacteria without regard to the vessel from which it was drawn.

These pyogenic microbes seemed to retain their virulence unimpaired throughout many generations. In man, the organisms are of widely varying virulence, and may be introduced under varying circumstances which either favor or militate against their growth. Their numbers may be great or small, so that they are sometimes defeated in their contest with the tissues, and at other times, when in great number, may produce a frankly local process or one of a spreading character. Consequently there is no pus-microbe, the injection of a culture of which will produce in all cases a septicemia in man. We must hasten to add that we do not as yet know all the conditions which are required in order to produce septicemia. Some of the favoring conditions are known and these will be presently discussed.

Some authors (Monod and Macaigne) distinguish between a *primary* and a *secondary septicemia*, the former being that in which only an insignificant point of entrance is noted, the latter that in which much inflammatory disturbance exists at the points of entrance of the microbes into the body.

The *dissemination of pus-microbes* from the point of entry into the blood has been the object of much study. In the case of the primary septicemia mentioned—usually instances in which an inoculation of very virulent bacteria has been effected—the micro-organisms may be carried with great rapidity into the blood, conceivably by direct introduction into the capillary vessels in the case of traumatism, but usually by the lymphatic route.

Halban, whose researches on the lymph-glands in pus-infection will be presently discussed in detail, denies the occurrence of bacterial *transmission by blood-currents* from the bleeding wounds. In addition to arguments, he presents the records of simple but seemingly crucial experiments. Rabbits were wounded in one of their legs and, while the wound was bleeding, a *dose* of a virulent culture of anthrax bacilli was wiped off upon the wound. The animals not treated died in twenty-four or thirty-six hours; but when the leg was amputated at the shoulder-joint two or two and one-half hours after the infection, death did not occur. This proves that the infection was arrested for two hours in the leg, and as the lymph-glands showed abundance of bacilli, it is evident that Schimmelbusch is mistaken in assuming tha[t] pathogenic bacteria pass directly into the blood in the infection of bleeding wounds.

As is well known, the chemotactic power of the pus-microbes i[s] very great—that is, the leukocytes are attracted toward these bacteri[a] with especial force. The bacteria are often enclosed by the leukocytes and, if alive when thus taken up, as maintained by Metschnikoff, the[y] may retain their vitality even when transported in this way to great dis[-]tances. That living bacteria do pass into the blood by way of th[e] *lymph-passages* has been frequently demonstrated; and their direc[t] introduction into the lymph-spaces by open wounds favors this mod[e] of transmission very greatly.

Leaving out of present consideration their initial local effects, man[y] of the bacteria deposited in the lymph-spaces are quickly carried to th[e] nearest lymphatic glands; or sometimes they may set up a more o[r] less violent *lymphangitis*. This inflammation may be limited to rednes[s] and tenderness indicating the lines followed by the lymph-vessels, or i[t]

may be of a suppurative character, in which case one or more abscesses will develop in the course of the lymphatics.

When *granulations* are present, the older and more highly differentiated tissue of the body is protected, as Billroth argued and as Leber has so well demonstrated, by a wall-like aggregation of leukocytes, new connective-tissue corpuscles, and attendant new blood-vessels. The lymph-spaces are therefore closed toward the wound, and before they can be opened the granulation-tissue wall must be broken down. This is well illustrated by the well-known clinical fact that probing an old sinus will often cause an erysipelas to develop—that is, the probing causes a lesion of the granulation-tissue wall through which the bacteria enter.

W. Noetzel has recently experimented upon this subject. He denuded large surfaces or made deep pockets in the backs of sheep and packed or dressed them with sterile gauze. When healthy granulations had been established, experiments with microbes and toxins were instituted. As inoculation material, cultures of splenic fever bacillus were used, and since the sheep is highly susceptible to anthrax, the entrance of the bacilli into the blood would be proved by the animal's death from that disease. In no case when bacteria were spread upon the intact granulations was an inoculation effected. Control-animals inoculated with a smaller number of bacteria and over a much smaller surface of a fresh wound died in thirty hours. When the granulations were injured during the dressings the anthrax bacilli found entrance, causing the animal's death. Billroth had performed practically the same experiment, instituting granulating wounds on the backs of dogs and applying pus from suppurating human wounds upon the granulating surface. No reaction followed; but when the pus was applied to a fresh wound, symptoms of intoxication and septicemia soon developed.

The *relation of the lymphatic glands to the resorption of bacteria* from the cellular tissues is most important. It is generally conceded that the function of the lymphatic nodes is, so far as infection is concerned, to filter out and destroy bacteria. They act also upon bacterial toxins.

The recent studies of Josef Halban (1897) have added much to our knowledge of this subject and are worthy of consideration.

When the yellow pus-microbe was introduced into the leg-tissues of an experimental animal, varying periods elapsed before the bacteria were demonstrable in the regional glands, depending first upon the mode of introduction. If the bacteria were not suspended in fluid, but were rubbed into the subcutaneous tissue, they did not appear in the glands until four hours had elapsed, a circumstance due to the lack of fluid which enabled the microbes to be taken up quickly by the lymphatics. Again, the *site of the injection* was found to be important. If the fluid was introduced into the muscular tissue, the bacteria were discovered in the glands at the end of one hour. Muscular activity was considered an active agent in causing a rapid movement of the microbes into the lymphatic vessels.

More surprising and novel was the demonstration that some kinds of bacteria could be found in the glands much sooner than others. Thus, the Micrococcus prodigiosus was demonstrable in the regional glands a few minutes after injection; the Staphylococcus pyogenes in one hour, and the anthrax bacillus only after two and one-half hours. Halban explains this difference by arguing that the microbes are attacked with varying energy by the glands, so that those micro-organisms which are slightly or not at all influenced are rapidly demonstrable, while those energetically destroyed are demonstrable only after they have overcome the resisting power of the gland. Halban showed, furthermore, that the *pathogenic bacteria are demonstrable* much *later* than the non-pathogenic, and, in addition, that the more virulent the microbe, the more slowly was it susceptible of demonstration.

When the bacteria gain entrance to the glands, they are *demonstrable at first in small number*, increase in number rapidly, reach a maximum, again numerically diminish, and finally disappear. After the microbes have once appeared in the glands, one or two hours at most elapse until they have disappeared. There is now a latent period in which, for five or seven hours, absolutely no micro-organisms, or in unusual cases 50 or 60 bacteria, are discoverable in the regional glands. After this latent period, the bacteria again appear as before, a maximum is reached, the number diminishes, and at length they disappear again. This series of changes can be repeated a number of times, the final outcome depending on whether the bacteria are pathogenic or not. The non-pathogenic finally disappear entirely; but the pathogenic increase and lead at last to the death of the animal. The

alternating appearance and disappearance of the bacteria represent, according to Halban, the varying struggle of the bacteria with the bactericidal elements of the glands. "Now," says Halban, "if we represent graphically this cyclical appearance and disappearance of the bacteria by a curve in which the abscissas indicate the time and the ordinates the quantity of bacteria, we obtain a curve which strongly recalls the temperature-curves which we are accustomed to see in septic diseases. And since my later experiments have shown me that a certain congruity exists in the relations between the internal organs and the lymph-glands, it seems to me that in this cyclical appearance and disappearance of the bacteria in the organs we have an experimental basis for understanding the remarkable fever relations in septic diseases."

Another striking fact, susceptible of easy clinical verification, is experimentally demonstrated by Halban. The glands respond to infection by a rapid *increase in their lymphoid substance.* After ten days' local infection with Staphylococcus pyogenes, the volume of the regional glands is augmented twenty or twenty-five times, without any microscopical change except the increase in the lymphoid substance. Halban adds that, in spite of the presence of a local abscess, the staphylococci in the enlarged regional glands are scarce (sometimes 200). Hence he concludes that, with the increase in the number of bacteria gaining entrance into the lymphatic vessels, the glands themselves increase in size until they are able to cope with the microbic enemies and prevent their growth in the gland-substance. That the non-pathogenic bacteria pass through the lymphatic glands is proved by the fact that they were found in the viscera a few minutes after injection; but the pathogenic organisms made their appearance there only when many hours had elapsed after they had been observed in the lymph-glands.

Pyogenic bacteria once introduced into the blood may grow there and increase in number, producing septicemia; they and their products may be killed or neutralized in the blood by the action of the chemica bodies called by Buchner sozins and alexins, and by the leukocytes they may be deposited in various distant structures, where they becom locally active and institute pyemia; they may be destroyed by the tissue cells of the parenchymatous organs—liver, spleen, bone-marrow, etc. or, finally, they may be excreted in a living state by the glandula excretory organs.

Pathologists are now inclined to regard the pyogenic staphylococ as the organisms most frequently engaged in metastatic suppurativ processes, while the streptococci are thought to limit their activit more closely to regional inflammation. Nevertheless, there are som clinicians (v. Bergmann) who strongly oppose the notion that we ca legitimately separate the micro-organisms in this way. For the prese we must forego the temptation to draw hard and fast lines between t septic effects produced by these great pyogenic groups.

The gonococci are now proved to be capable of producing not on local but metastatic pyogenic effects. Wertheim has shown, by caref microscopic examination of an excised piece of bladder mucous me brane from a case of gonorrheal cystitis, that "in the epithelium a connective tissue an extraordinary number of gonococci were prese In the submucous tissue there was a considerable number of capillari and very small vessels filled with gonococci, partly degenerated a partly well preserved. In many places there was complete obstru tion of the lumen; in others a mural projection was seen. The gon cocci were found only in capillaries and in the precapillary veins, wh the arteries were free." Prof. Jadassohn adds that in this way it shown that metastases of the gonorrheal process can occur, and th too, through a true gonorrheal thrombophlebitis. That the joints gonorrheal rheumatism contain gonococci has been proved by num ous cultural as well as bacterioscopic examinations. Welch has sho that endocarditis in association with other pyemic morbid changes m

be due to the action of gonococci. Gonorrheal arthritides and the associated visceral pyogenic lesions are to be regarded as expressions of true gonorrheal pyemia.

Not only gonorrheal rheumatism but also acute rheumatic polyarthritis is to be regarded as of a septic, if not pyemic, character. Numerous observers (Guttmann, Sahli, Barbier) have found pyogenic cocci in the joints in acute rheumatism; but no specific organism has thus far been found. The fact that an angina has preceded many cases of the disease (older writers, and later Buss, Eichhorst, Jaccoud) has seemed to lend probability to the infection theory by supplying a demonstrated atrium. Then, again, the clinical signs are typical of a metastatic affection, and the post-mortem findings—cloudy swelling of the myocardium, liver, and spleen, and the frequent endocarditis—seem to point with conclusiveness to the pyemic character of the malady. For the present, however, we await further bacteriological study of the disease.

Pathological Anatomy.—In those violent cases of sepsis in which death takes place within a few hours after the infection, a careful anatomical study of the tissues at the autopsy may reveal no lesions and may fail to throw light on the nature of the disease. Dependence is then to be placed upon the discovery of the active pathogenic agents by cultural methods, using material from the blood, the bone-marrow, and the viscera, while the clinical history has often to be utilized in making up the diagnosis, especially where no infection atrium can be found. But if the disease has not been so quickly fatal, if the toxins set free by the micro-organisms have had time to act, and if elevated temperature has for a time exercised its influence upon the body, many of the tissues will present evidences of *cloudy swelling* or even of fatty degeneration. We are told in the text-books on pathological anatomy and clinical medicine to expect an *enlarged spleen*. But the spleen is often of ordinary size, even in cases in which the blood findings are positive (M. Hahn). The spleen when enlarged constitutes often a palpable mass in the left hypochondrium, and is often referred to clinically as an acute splenic tumor or swelling. On pressure, the pulp yields readily to the finger, and inspection shows a minimum of connective tissue. A large quantity of blood in the organ helps to give the tissue a bright red appearance. The *marrow of the long bones* is similarly softened, redder than usual, and congested (Kolisko). It will be seen that these indirect or remote changes are not peculiar to pyogenic disease, but are common to the acute infections.

Much more characteristic are the morbid alterations which follow in the direct track of the infection. At the infection atrium nothing may be found—a few hours may suffice for the closure and obliteration of the wound (*e. g.*, a hypodermic puncture). Sepsis taking origin in this way is clinically known as a **cryptogenetic** or **spontaneous infection.**

Leube has described a number of such cases and has laid down rules for their diagnosis; but usually a local lesion will be noted—a simple abscess, a spreading phlegmonous inflammation, or a focus of suppuration under pressure. Kocher calls attention to the fact that systemic infection is more likely to occur when the bacteria at the primary site of disease have had to grow against much cellular resistance. In this way, if the bacteria overcome the tissues, they will have a heightened virulence. Kocher cites cases from his own practice in which the osteomyelitic form of pyemia occurred after such primary infections.

A *carbuncle* is especially prone to produce septicemia because the toxins of the pus-microbes are forced rapidly into the circulation and because the bacteria themselves can easily pass into the lymphatics or even into small veins.

When extensive surfaces capable of very rapid absorption are suddenly flooded with infected fluids, acute toxemia is likely to result very quickly in death. An example of such a morbid anatomical catastrophe is to be found in the rupture into the abdominal cavity of a gall-bladder distended with pus or mucopurulent fluid. But when acute chemical poisoning is withstood, the system is swept with bacteria, which, by way of the blood, are carried in a few minutes to all parts of the body. These organisms may be demonstrated then in the blood and in the parenchymatous viscera.

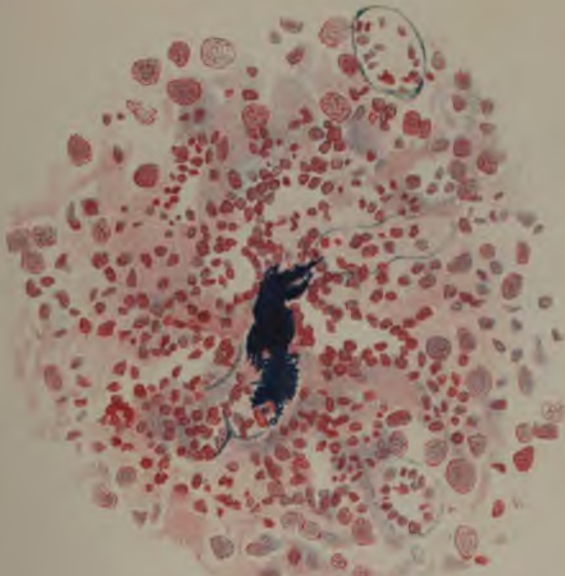
The present consensus of opinion among bacteriologists is that the streptococcus of Fehleisen, which was once thought to be the specific microbe of erysipelas, is capable of producing suppuration. This means it is identical with Streptococcus pyogenes. Petruschky reports a number of cases in which the same organism was cultivated from the erysipelatous skin and from abscesses in the same patient, evidently anatomically connected with the dermatitis. Erysipelas has long been recognized as a fruitful source of blood-poisoning. Many observers have shown that during attacks of erysipelas, streptococcus abscesses occur, and that these, as well as other forms of septic disease, are common either in the course of erysipelas or as sequelæ.

The changes taking place in the lymphatic vessels engaged in carrying pyogenic organisms from an infection atrium may be so slight that no clinical or post-mortem change can be made out. But a *lymphangitis* often occurs—indicated clinically by red lines widening here and there—running over the skin if the inflammation be near the surface of the body, and converging toward the lymphatic glands of the region. This lymphangitis may become locally violent and terminate in suppuration. The vessel then becomes the center of an abscess. Such abscesses may form in numbers along the course of the lymphatic vessels. As a rule, however, the bacteria proceed to the regional glands without suppurative lymphangitis. The morbid change in the glands we have already described for those instances in which suppuration fails. It is always possible, however, that a flood of microbes may be carried to the regional glands by the lymphatic vessels with such rapidity, and in association with so much bacterial poison, that the cells are unable to dispose of them. *Suppurative lymphadenitis* will then be found. In the cut section of the gland small isolated abscesses may be noted located in the midst of the pulp, or, at a later stage, the gland-capsule may contain nothing but a broken-down mass of shreddy tissue mixed with pus. Naturally, such glands are not only incapable of further protecting the system, but are themselves a menace to its welfare, constituting new foci of disease. The resisting fibrous capsule soon breaks down altogether at some point, and the pus, escaping into the loose areolar tissue, forms abscesses (*peri-adenitis*).

Once the microbes have passed the lymphatic-gland barrier, they are poured with the lymphatic current into the blood. Swiftly they

PLATE 5.

Infiltration of muscular tissue with streptococci in a case of septicemia of man. The blood-vessels contain numerous leukocytes, but none are found in the surrounding connective tissue (Warren's *Surgical Pathology*).



Capillary embolus of streptococci in a sarcoma. A round-cell infiltration is seen in the sarcomatous tissue about the embolus. (Case of fatal septicemia.) (Warren's *Surgical Pathology*.)

are borne to all parts of the body, being constantly subject to the destructive influence of the leukocytes and the chemical protective bodies of the serum (sozins and alexins of Buchner), until they are either destroyed in the blood-current or in the capillaries of the viscera (spleen, liver, etc.) and in the red bone-marrow, or are excreted by the emunctory glands. But while they are alive in the blood, they may be found clinically or post mortem by cultural methods. The *toxins* of the bacteria are also to be *found in the* circulating *blood*, as we know from Marmorek's experiments, in which it was shown that for a month after recovery from streptococcus infection, the serum of the animals used was poisonous to other individuals of the same species. Antitoxins are also developed, as already shown (Marmorek, Petersen; denied by Lubarsch).

A leukocytosis (temporary increase in the number of white blood-corpuscles) is the common result of suppuration, and occurs as well in septicemia and pyemia.

Changes in the blood-vessels occur in both septicemia and pyemia; but it is chiefly in connection with pyemia that the subject has to be considered. The micro-organisms get into the blood in two well-recognized ways: first, by the lymphatic route already described; second, by the direct invasion of the blood-vascular walls. (The direct entrance of pathogenic organisms into the small vessels of wounds, as upheld by Schimmelbusch, is denied by Halban.)

When an abscess develops about a vein, *thrombophlebitis* occurs, the process beginning in the adventitia of the vessel, which responds to infection exactly as would any other vascularized connective-tissue structure. If drainage is not effected, the wall of the vessel becomes more and more inflamed by contiguity of tissue until the intima is reached. This membrane becomes swollen and ill nourished, and no longer supplies those well-recognized conditions upon which the integrity of the blood depends—in other words, coagulation occurs. It is most important to remember that the thrombus formed is at first aseptic, and remains so until bacteria have invaded it in the same way that the wall of the vessel was attacked—*i. e.*, by contiguity of tissue, and not by rapid dissemination through fluids. That the thrombus is at first aseptic is proved by the fact that the emboli set free from thrombi in the sinus-phlebitis of otitis do not produce secondary abscesses. The wall of the thrombosed vessel is more and more invaded by the microbes until it is broken down altogether at certain points. In simple infections, purulent liquefaction of the wall takes place, the natural color of the vessel giving place to a dirty gray, and the thinned wall yielding at some point to slight pressure of the probe. The suppurative changes involve the vessel-wall as far as it is surrounded with pus. The thrombus may extend only a short distance, or it may spread many inches along the course of the vessel, and may even run out into branches of the chief vein. At first, as has been said, the thrombus is not infected. It is firm and elastic, and gives the vessel a cord-like feeling upon palpation. But when the pyogenic process has liquefied a part of the vessel-wall, the microbes flourish in the coagulated blood, which offers but little mechanical or vital resistance, and speedily becomes broken down (partly liquefied) into a semi-fluid

mass in which parts of the thrombus float. When no portion of the infected thrombus intervenes between the broken-down part of the vessel's contents and the fluid blood, the conditions required for the occurrence of embolism are furnished, masses of infected thrombus are carried to distant viscera, and infected infarcts are produced, resulting in the formation of secondary or metastatic abscesses. Should the abscess about the vein be drained, and an exit be afforded for the broken-down matter in the vein, the suppurative process may be arrested, and the uninfected thrombus may form an effective temporary barrier to the further spread of the disease into the blood. This temporary barrier may be converted into a permanent one by the substitution of connective tissue growing from the vessel-wall for the thrombus.

When emboli are carried into the blood, they are not arrested in their course until they reach a part of the vascular tubage which has a smaller diameter than that of the embolus. Their arrest is therefore a mechanical matter. Abscesses may or may not develop from infected emboli. The emboli may not carry a sufficient number of micro-organisms to the point of arrest to overcome local resistance; other conditions of infection, also, may be absent. But, as a rule, the conditions are highly favorable for infection, because the plugging of the vessel produces an area of imperfectly nourished tissue in which the microbes rapidly flourish. First, an endarteritis occurs at the site of embolism; the vessel-walls are successively invaded, this time from within outward, and the pus, having got into the perivascular tissue, speedily finds its way about the wedge-, cone-, or cylinder-shaped mass of anemic tissue. When such a morbid anatomical incident has occurred, a sphacelus may sometimes be found in parenchymatous organs, surrounded by pus. Should the embolism have occurred in the bone, a sequestrum will be formed.

It is in the bones, however, that localization of bacteria from the blood is especially prone to occur by the process known as *mural implantation*. Micro-organisms floating in the blood, finding points in the smaller vessels and capillaries where the current moves but slowly, become arrested, and, together with white corpuscles, endothelia, and fibrin, produce thrombi in which the bacteria grow. Various circumstances, such as anatomical conformation, exposure to cold and trauma, furnish opportunity for the mural implantation of microbes. Doubtless many such localizations result in the death of the bacteria and local healing; but abscesses beginning in the endothelium of the vessel and extending through the vessel-wall into the surrounding tissue are very commonly found in pyemia.

The *kidneys* are especially prone to purulent inflammations on account of the fact that they excrete bacteria (Biedl and Kraus). These inflammations often affect the glomeruli, in which the circulation is slow.

Of course, the greatest number of emboli find lodgement in the *lungs*, since the majority of vessel-invasions occur on the venous side of the circulation. But the branches of the pulmonary vessels are relatively large, and many masses are small enough to pass through them into the pulmonary veins, which deliver them to the systemic circulation,

through which they are carried to the remotest parts of the body. The distribution and lodgement of emboli, then, correspond in large measure with the distribution of the blood-mass, many being observed in the liver, brain, spleen, kidneys, etc.

Symptoms and Course.—The symptoms and course of pyogenic bacteriemia are very variable, so much so that, until very recent times, attempts were well-nigh universally made to divide the disease into a number of parts corresponding to its clinical manifestations. At the risk of some clinical confusion we are obliged, as we must always do when possible, to preserve the unity of pathology and describe under a single general heading all the symptom-groups of the malady.

Common to all acute forms of pyogenic bacteriemia are certain symptoms already referred to as due to the *resorption of toxic substances* elaborated by the microbes. The circulatory mechanism is usually profoundly affected by the activity of these chemical substances. The heart's action becomes rapid, the tension of the blood in the arterial system is lowered, and, when fever and intoxication are at their height, the skin presents a bluish appearance, due to the stagnation of the venous blood. As septic poisoning deepens, and the bacteria, overcoming local and regional resisting forces, migrate to distant parts of the body, the heart beats more and more rapidly, the pulse often running up to 150 and more per minute, until, just before dissolution, it cannot be counted.

The *temperature*-record is in some forms of septicemia almost characteristic, as we shall see. The manifest tendency in subacute sepsis is for the temperature, after a sudden rise to 104° F. or more, to become lower every morning, only to rise to the maximum toward evening. In pyemia in its various forms, *chills*, often very violent, are the outward manifestations of metastatic movements of the bacteria, which result in the formation of secondary and tertiary abscesses. When recovery from sepsis takes place, the fall in temperature to normal, or almost to normal, is often surprisingly rapid, if the primary focus of infection is quickly removed, as by amputation. When recovery is due to slow drainage, the temperature-curve returns gradually to the normal line, but the morning remission already mentioned continues to recur. A remarkable fact, giving rise to the greatest clinical difficulty, is to be found in the circumstance that the temperature-elevation is often slight as compared with the pulse-rate. In other words, the pulse-rate may indicate profound sepsis, while the temperature may be comparatively low. This is due, it seems, to the fact that certain pyogenic organisms elaborate not only a chemical body which elevates the temperature, but one which tends to lower it. The preponderance of the latter in the by-products of the micro-organisms of a given case lowers the temperature, while the heart, uninfluenced, beats rapidly. This is especially true of certain forms of sepsis taking origin in abdominal pyogenic affections.

The *nervous system* is at times *stimulated* by sepsis, so that the patient does not realize his own jeopardy; but, for the most part, depression is noted. For the first few days the patient sleeps much, is roused with some difficulty, responds slowly to questions, and will lie for hours in a state of stupor. At first, the mind, though acting slowly,

is clear; but later, hebetude is followed by stupor, stupor by coma, and coma by death.

The *respiratory system* is active enough in the milder forms of sepsis; but a bluish tinge of the face is usually seen as the poisoning deepens, proving that the blood is but imperfectly aërated.

The *glands* of the skin and of the mucous membranes are not active in sepsis. The tongue becomes dry and coated; and, as the disease advances and deepens, becomes marked by reddening of the edges, pointing of the tip, and the collection of sordes upon the dorsum. Perspiration is often profuse, and the loss of a considerable volume of water in this way may cause a temporary feeling of depression. Since bacteria are known to be excreted by the sudoriparous glands, the use of violent sudorifics has been proposed as a therapeutic measure in sepsis; but the injurious effects of these agents on other functions has prevented them from becoming popular.

That form of septicemia in which no focus of suppuration exists, but in which a fresh wound is infected with bacteria which seem to pass rapidly into the blood, is sometimes spoken of as *primary septicemia.* This form is especially dreaded because of our inability to guard against it, from the fact that the wound may be an accidental one, that the extreme virulence of the infection can be known only by the outcome, and that treatment is usually of no avail. We refer to those violent forms of infection in which the prick of a pin or a needle is followed by death. Medical men are especially in dread of such infections. In making post-mortem examinations, especially of fresh bodies, inoculation may be effected through a slight punctured wound. The infectious material is of especial activity when it is derived from fresh bodies in which the microbes have flourished before death, so that their virulence is likely to be heightened, especially if they have had to grow against a considerable tissue-resistance, as in peritonitis or acute abscess-formation. The operator thinks nothing of the puncture he has received, often does not interrupt his work to dress the wound, and is surprised a few hours afterward to find himself suffering from a chill followed by high temperature. A few red lines running up the arm to slightly swollen lymph-glands call attention to lymphangitis and beginning lymphadenitis, and make more certain the diagnosis of acute septicemia. Delirium followed by coma is associated with all the other signs of violent depressant intoxication, the pulse and respiration becoming more and more enfeebled until death ensues. In such extremely violent cases of blood-poisoning we must assume that the noxious agent is bacterial, that the micro-organisms are of exceptional virulence, and that, in spite of the resisting power of the tissues, they are capable of growing very rapidly and of elaborating their toxic products with great rapidity. The Streptococcus pyogenes is the microbe usually thought to be active in these cases.

Much less acute and violent is the usual form of septicemia. When a patient has had for some time a focus of suppuration which has drained but poorly or not at all, blood-poisoning, which in this case may be called *secondary septicemia*, is likely to set in. The bacteria make their exit from the abscess-cavity through its walls, ruptured by tension or by violence (*e. g.*, by the surgeon's knife), and are carried to the blood by

the lymphatics. The long-continued resorption of toxins from the pent-up bacteria causes a remarkable lowering of the resisting power of the blood and distant tissues, so that the bacteria are able easily to produce their characteristic effects upon them. When the surgeon knows that his drainage is imperfect, he fears that a daily afternoon rise of temperature with morning remissions denotes a beginning septicemia. The morning temperature may recede to normal or even to a point below normal; the evening temperature goes up to 103° or 105° F. The patient is bathed in a sour perspiration when the fever is high. The urine is correspondingly high-colored and scanty, and may contain albumin and casts. The tongue becomes coated on the dorsum, dry, often cracked, and red at the edges. The breath is often foul smelling. The pulse is usually rapid and feeble. The bowels, at first inclined to be confined, are in the later stages often relaxed, and the passages thin and foul smelling. The mind for some time is capable of responding to demands of the will, so that when the patient makes effort he can concentrate his attention and answer questions. Hebetude is early observed, however, the patient often lying for hours in a stupor unless aroused to take nourishment or medicines. These so-called "typhoid" symptoms deepen, as time passes, into a comatose state in which the passages are involuntary, foods are taken only when poured into the mouth, the skin becomes dry and harsh, the pulse becomes rapid and feeble, and death is ushered in by failure of the circulation and respiration—sometimes due to hypostatic pneumonia. The likeness of this form of septicemia to typhoid fever (which is regarded by many as a specific form of intestinal septicemia) is so marked that close differentiation is sometimes necessary. Septicemia of this clinical variety may be due to staphylococci as well as to streptococci; and it may be associated with, or follow, abscesses or erysipelas. Slow septicemia may go on for months, as every surgeon of experience can testify. The writer recalls the case of a man who had had several écrasements for tuberculosis of the knee and tubercular sinuses. The suppuration at the site of mixed infection continued in spite of drainage-tubes passed through the knee and leg in all directions; the patient's resisting power diminished instead of growing, and the daily rise of temperature became greater and greater. Marasmus increased until the patient was reduced to a condition of debility pitiable to see. At this juncture, the formation of metastatic abscesses (pyemia) being feared, amputation through the thigh was performed. The patient was in one week a changed man. His temperature became normal, his sweats ceased, his urine cleared, and, in a word, he made a rapid recovery. As he was a tall man and had lost much weight, he gained more than fifty pounds during the rebound to health.

The *chronicity or* the *acuteness* of septicemia is due to a variety of circumstances affecting the host as well as the microbic parasite, and we can by no means conceive that there is any quality inherent in the micro-organisms alone which necessarily brings about a given course of the disease. Recognizing the importance of removing or ameliorating all conditions that favor the spread of the micro-organism, it is clearly all the more our duty to recognize the non-essential character of septicemia in order to combat it.

Pyemia is, as we have said before, not to be sharply distinguished from septicemia, since it differs from it only in the formation of metastatic pyogenic deposits. The typical cases of pyemia are easily distinguishable clinically from septicemia by the finding of these secondary abscesses; but when the abscesses are deep-seated in inaccessible viscera, their existence may often be only surmised. The occurrence of general intoxication and of true septicemia with metastatic abscesses has often been noted, the combination being known clinically as *septicopyemia*.

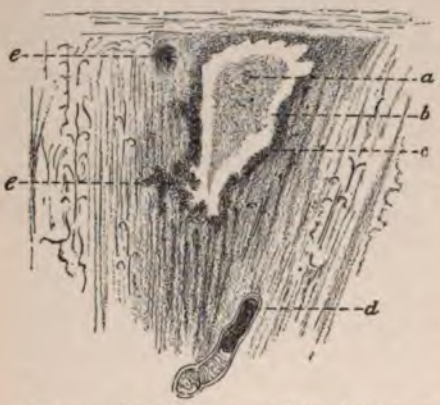


FIG. 40.—Pyemic abscess of the kidney: *a*, central dead tissue; *b*, suppurative zone; *c*, zone of granulation-tissue; *d*, embolus in a branch of the renal artery; *e*, *e*, small infiltrated suppurative spots (Thoma).

Pyemia differs clinically from septicemia, as has been said, in the formation of metastatic abscesses. These abscesses, when formed by the lodgement of infected emboli in vessels distant from the primary focus, arise in the artery or vein itself in a thrombo-arteritis or thrombophlebitis. The inflammation rapidly extends to the anemic tissues within the area supplied by the vessel. Hence, the increment of intoxication which takes place when an infected clot becomes suddenly lodged in a previously intact area is enormous, and the system at large responds clinically by a *rise of temperature* almost invariably preceded by a *violent chill*. The chills, then, are a very good index of the occurrence of embolism, and serve to call the attention of the surgeon to the element of pyemia added to the septicemia.

A clear *picture of* typical *pyemia* should be fixed in our minds. Billroth has an excellent account of a hypothetical case which he related in his lectures. As Billroth's experience extended over part of the pre-antiseptic as well as the antiseptic age, he had doubtless seen many such cases as the one he describes. He says: "Imagine now that a wounded person has been brought into the hospital, in whose case you recognize a complicated fracture of the leg just above the ankle, with extensive contusion. The injury has occurred by the impact of a very heavy falling body. You have examined the wound and found a transverse fracture of the tibia, and you have decided for conservative treatment. Let us suppose that you have applied a dressing such as was used in former times without antiseptic precautions. The patient feels well in the beginning, and has but little fever up to about the third or fourth day. Now the wound begins to be more strongly inflamed, secretes relatively little pus; the skin in the neighborhood becomes edematous and red, the patient's fever increases especially in the evening, the swelling in the neighborhood of the wound increases and slowly extends farther; the whole lower leg is swollen and reddened, the ankle-joint very painful, and on pressure upon

the leg there flows slowly from the wound a thin, foul-smelling pus. The swelling remains limited to the lower leg, there is no involvement of the sensorium, no sign of intense acute septicemia; the patient is extremely sensitive at every dressing, peevish and disheartened. A remittent continuous fever has established itself, with tolerably high evening temperature and increased pulse-frequency. The pulse is full and tense, the appetite is quite lost, the tongue is heavily coated. We find ourselves now at about the twelfth day after the injury. Out of the wound flows very much pus from different directions. Somewhat farther above the wound distinct fluctuation is to be noted. With difficulty the abscess-cavity can indeed be emptied toward the wound by pressure, but the outflow is very limited, and it is consequently necessary to make an incision at the point named. This is done and a moderate amount of pus is evacuated. Some hours afterward the patient gets a severe chill, then a dry burning fever, finally a very pronounced sweat. The appearance of the wound improves somewhat, but that does not last long. A new abscess-cavity is noted farther back upon the calf in the neighborhood of the wound. A new chill occurs, new counter-openings are necessary, now here, now there, in order to provide a sufficient exit for the pus, which is formed in moderate quantities. The left leg being the injured one, some morning the patient complains of severe pain in the right knee-joint, which is somewhat swollen and painful upon every movement. The nights are sleepless, the patient eats almost nothing, drinks very much, is much reduced, becoming thin especially in the face. The skin becomes slightly yellow in color. The chills are repeated, and the patient now begins to complain of pain in the chest. He coughs a little, but brings up only a little sputum. Upon examination of the chest you note a pleuritic exudate, as yet moderate, upon one or both sides, but the patient does not complain very much of it. So much the more, however, does he complain about the right knee, which is now very much swollen and contains much fluid. Since the patient sweats a great deal, the urine becomes concentrated and occasionally contains albumin. Bed-sores are finally added, but the patient scarcely feels them. He lies there in part benumbed, and mutters in a low tone to himself. About three weeks have now passed since the injury. The wound is dry, the patient looks very ill, the face and neck are especially emaciated, the skin of a strongly icteric color and cool; the eyes are dull, the tongue, trembling when put out, is quite dry, the temperature is low, and elevated only in the evening. The pulse is very small and frequent, the respiration slow, and the breath has a characteristic cadaveric odor. Finally the patient becomes unconscious, and may remain in this state perhaps twenty-four hours more before death occurs."

Pyemia, in the case of wounds not treated antiseptically (or aseptically), often takes the course described by Billroth. In modern practice pyemia is quite infrequently met with, except when injuries are much neglected.

Even yet, however, it is not uncommon for us to meet with pyemia taking origin in the veins of the face and sinuses of the cranium. The *facial veins* which communicate with the sinuses of the brain are especially likely to become inflamed and, often undergoing thrombo-

phlebitis, set emboli free to pass to distant parts of the body. The pyemias taking origin in the upper lip, involving the facial vein, are likely to end fatally in a few hours or three or four days.

FIG. 41.—Emboli in the branches of the pulmonary artery, the upper more closely adherent to the wall and shrunken (Thoma).

The following is a typical case published by Hentschel in the Surgical "Festschrift" for Benno Schmidt (1896).

"The patient, whose Czechish nationality makes it difficult to understand him, had some days ago a small furuncle on the upper lip, which was incised by a physician, who observed that a trace of pus escaped together with some blood. Two days later the upper lip and face were strongly swollen, and the same physician made four superficial incisions perpendicularly to the lip. It is said that neither pus nor blood escaped. Late in the evening of the same day the patient entered the hospital.

"His condition on entry was as follows: The young, powerfully built man, somewhat somnolent, had a labored respiration and a very small and frequent pulse; the forehead, eyelids, nose, and lips were distended with well-marked edema; the lips were very much protruded, slightly open, and between them was visible the equally swollen tongue. The answers of the patient were given in a characteristic grunting tone. Aside from the symptoms of acute inflammation yet to be described, the facies resembled in form and expression exactly that of a myxedema patient. The upper lip was so strongly swollen that the nares were in part closed. The lip was covered with dirty brownish-red scabs, which were removed, disclosing the entire surface covered with numerous purulent foci, large and small. The furuncles observed, in all stages of development, occurred at the border of the lip and extended far into the mucous membrane toward the gums. Furthermore, some wounds, apparently produced by incisions, were found on the upper lip, from which was discharged a clear yellow serum-like fluid. The disease of the upper lip extended beyond the left angle of the mouth. The left half of the lower lip was involved in quite the same way. In the region of the left nasolabial fold were some blebs filled with a clear watery fluid. Upon the left cheek an extensive network of veins shimmered dark blue through the skin. The conjunctivæ were strongly chemotic and reddened. In the connective tissue of the left

lower lid were to be found a few pus-foci. In the lungs were to be heard everywhere subcrepitant and large bronchial râles. The heart's action was stormy, but the pulse became always weaker and more frequent, so that, even in the night, the upper lip and the diseased half of the lower lip were deeply incised with the knife, whereupon tolerably marked bleeding occurred from the angle of the mouth. Energetic irrigation with sublimate, iodoform-gauze tamponade, ice, camphor, alcoholics, constituted the treatment. In spite of the energetic application of stimulants, death occurred on the next day at seven o'clock in the morning, with symptoms of heart-failure. Post-mortem examination was made five hours after death. The anterior facial vein was thrombosed as far as the angle of the jaw. In the internal jugular vein no thrombi were demonstrable. The entire lung showed multiple pinhead to hazelnut-sized pus-foci, with numerous small hemorrhagic infarcts and patches of catarrhal pneumonia and pronounced edema in the spaces left free; the heart was relaxed, and its musculature showed moderate fatty infiltration. In spite of the most exact investigation, even with the use of the microscope, no pyogenic infection was demonstrable on the valves and in the myocardium. Small abscesses were noted in the liver and kidneys. The spleen was strongly swollen, rich in blood, and soft. A very careful bacteriological examination showed everywhere pure cultures of Staphylococcus citreus.

"This is the usual form of pyemia in which the secondary lesions appear in the joints and viscera."

Nicaise has described a clinical variety of the disease in which the abscesses appear with special frequency in the muscles, **myosite infectieuse.** E. Pfister[1] describes a case of the kind, which we may briefly abstract.

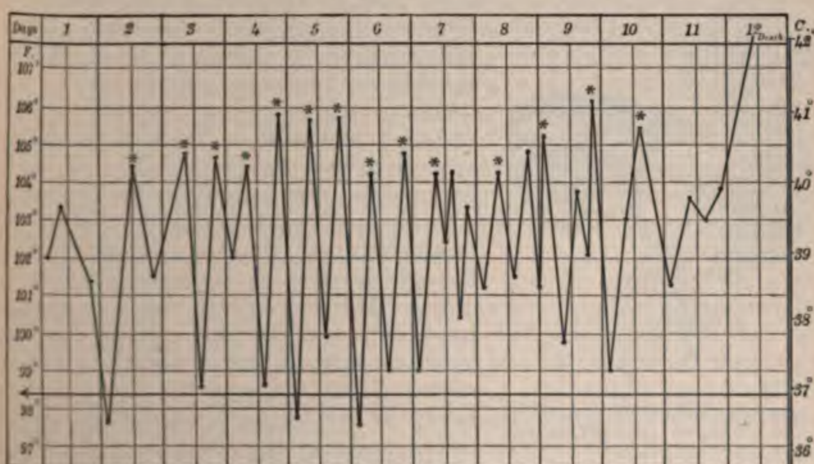


FIG. 42.—Temperature-chart in a case of pyemia with muscular localizations; * indicates a chill. The fall of temperature was frequently due to the use of the cold pack.

Kl., twenty-one years old, serving-maid. History: Patient called upon a physician on May 16 on account of a slight lymphadenitis of the axillary cavity, for which a small wound of the hand already cicatrized was held responsible. On the next day the temperature rose to 39° C. From May 19 the patient improved, and treatment ceased. She was not altogether well, however, at any time. May 31, the physician was again called on account of a prepatellar bursitis. At the same time fever was noted and a certain amount of dyspnea, so that the patient was at once taken to the hospital. On admission, June 1, the condition was as follows: Well-built, healthy-looking girl; anterior side of right knee swollen, skin reddened and moderately tense, distinct fluctuation over patella, patellar region moderately sensitive on pressure as well as spontaneously, no joint effusion. A diagnosis of prepatellar bursitis was reached, but no incision was made because purulent inflammation was not clearly apparent. Treatment was limited to rest and cold applications. At noon of the next day a pronounced chill was followed by a rise of temperature to 40.7° C. and by a sweat. After the sweat was past the patient felt as well as usual, but somewhat tired. On

[1] *Lang. Arch.*, Bd. xlix., H. 3.

June 3 the swollen bursa above the right patella was punctured, since the chills were repeated. The puncture yielded a sanguinolent, tolerably thin pus. An incision was then made for the application of drainage and the dressings were changed daily. The entire disease-picture recalled pyemia. On the seventh of the month the patient could see almost nothing with the left eye, but ophthalmoscopic examination revealed nothing. The left facial nerve was almost completely paralyzed. A pleuritic rubbing was present; the urine was without albumin. Every day one or two chills occurred and the respiration became frequent. On the eighth of the month the cornea of the left eye was diffusely opalescent; the bulb of the eye was pushed forward. On the ninth of the month the left arm and the left leg were almost completely paralyzed, so that the paralytic phenomena excited a suspicion of brain-abscess. On June 10 the upper part of the neck and the region of the ear began to be considerably swollen and tender. The paralysis of leg and arm seemed somewhat improved. On the left heel there was a fluctuating pustule about the size of a franc piece. The wound of incision at the knee was dark-colored and dry. On the morning of June 12 the patient died with hyperpyrexia.

At the post-mortem examination were found, in the first place, extensive muscular suppurations. About the sternocleidomastoid muscle, about the left upper arm and below the fascia of the triceps, and in the triceps itself, were found purulent infiltrations. A myocardial abscess, a subperiosteal and a subcutaneous pus-collection, a slight pleuritis, purulent gonitis, and, besides these, a distinctly recognizable metastatic ophthalmia and bursitis were noted. Streptococci were found in all the lesions.

These cases in which a predilection seems to exist for localization in muscular tissues—a localization which is thought to be caused by excessive muscular activity—are not common; but localization in the *bones* is of frequent occurrence. This form of bone-inflammation is spoken of as acute *osteomyelitis* or infectious osteomyelitis. It is specially treated in the chapter on Bones and their Diseases. Its clinical varieties are great, but the peculiarities of the inflammation, due entirely to the anatomical conditions supplied by bone-structure, are so characteristic that for a long time it was thought we had to deal with a special microbe. It is now known that any pyogenic bacterium may produce osteomyelitis just as it would produce a subcutaneous abscess. Localization of the bacteria circulating in the blood is effected by injuries to the bone, by the slowing of the blood-current about the epiphyses in growing children, by chilling of the part, etc. It is unusual for pyemia of the visceral type already described to follow upon ordinary osteomyelitis. Several bones, usually the long bones, are simultaneously or successively affected. When several bones are successively involved, those last affected are often much less seriously inflamed; indeed, the only manifestation may be a severe periostitis without necrosis. Staphylococci are often the causative agent in this form of pyemia, although streptococci are also frequently observed. The disease is often so violent in form that death occurs in a few days. In very acute cases death takes place before the bacteria, which have found lodgement in the bones, have had opportunity to reproduce themselves and cause abscesses. In other words, the clinical signs may be those of a bone-inflammation. Indeed, in such cases it is the septic poisoning which causes death.

FIG. 43.—Embolic obstruction of the trunk of the right pulmonary artery (Thoma).

On the other hand, the local manifestations of osteomyelitis may be very chronic, simulating tuberculosis, sarcoma, or even fibroma and osteoma of periosteum or bone (Kocher). These variations of clinical form belong to the chapters on Local Suppuration and Osteomyelitis.

Pyemia taking origin in *thrombophlebitis* may be due to inflammation of any vein sufficiently large to answer the anatomical requirements. But certain large veins in different parts of the body are especially likely to afford origin to pyemia, and the symptomatology of the disease as modified by the local conditions may be briefly considered.

Pylephlebitis.—Inflammation of the large branches of the portal vein is, in that commoner form of the disease in which the metastatic deposits are limited to the portal circulation, a sort of local pyemia. Any suppurative inflammatory process about one of the large branches of the vein may set up a pylephlebitis, the inflammation attacking successively adventitia, media, and intima, then bringing about a thrombosis within the vein. The commoner causes of purulent pylephlebitis are operations within the area supplied by the portal vein, hemorrhoidal inflammation, appendicitis, ulcers and carcinomata of the gastro-intestinal tract, localized purulent peritonitis, and suppurative retroperitoneal lymphadenitis. When the coagulum within the vein is softened and broken down, the loosened masses may be swept away in the blood-current, to be deposited in the hepatic branches of the vein. Only exceptionally are small masses of infected coagulum carried through the circulatory system of the liver to pass into the vena cava and cause abscesses in the tissues supplied by the systemic circulation. Hence, as a rule, the morbid anatomical changes are for the most part found in the liver, where abscesses develop about the veins in which the emboli have lodged.

Those emboli which plug vessels that supply areas having good anastomoses do not give rise to symptoms that enable us to localize the disturbance. But in well-marked cases of the disease we have not only the etiology to aid in diagnosis, but also icterus, tenderness over the portal region, swelling of the liver and spleen, and pyrexia associated with rigors (Eichhorst). Death usually occurs in pylephlebitis, this form of pyemia being responsible for many of the deaths in appendicitis.

Pyemia taking origin in acute and chronic otitis media—**otogenic pyemia** (Hessler), or *otogenic sinus phlebitis*—has been much studied in the past decade, although observations of the disease date back to the writings of Abercrombie in 1829 and of Lebert in 1856. The close anatomical relationship between the middle ear and the sigmoid sinus makes it easily possible for pyogenic processes to spread in a variety of ways to the great venous channel. The thin walls of the sinus are attacked from without, and the series of destructive coagulating and disintegrating processes already described take place until its interior is practically only an abscess-cavity. The thrombotic process may then extend downward along the course of the jugular vein, or masses of the coagulum may act as emboli, setting up metastatic disease at distant points. Purulent inflammation of the brain or its meninges may, however, prevent the full development of the pyemia by causing

death. A typical case of otitic pyemia is reported by Hessler in his monograph on otogenic pyemia (Jena, 1896).

"A girl twelve years old had otorrhea of both ears, following scarlet fever and diphtheria in the seventh year, with loss of membrana tympani, hammer, and anvil, on both sides. The left ear ceased running after one year, with total deafness. The right ear had discharged continuously, with almost complete deafness to speech. For eight days before admission a continuous infiltration and swelling were noted about the left mastoid process, so that finally the concha was lifted to a right angle from the head. There was no fluctuation, and the auditory canal was much swollen. The temperature for four days remained above 39° C. Upon chiselling out the mastoid process, the bone externally appeared almost unchanged, excepting that the vascular openings at the ordinary points were very much dilated; but in the deeper layers the bone was softened in a curious manner. At the posterior wall of the cavity of the mastoid process, which was of the size of a cherry, the dura had to be laid bare, but it was of a normal bluish glistening appearance. For the first eight days the patient felt perfectly well, and the wound-healing was normal, when suddenly vomiting occurred with pyemic temperature-variations, but without chills either at the beginning or later. There followed metastatic swellings and inflammations in the back of the right hand, the right shoulder, and the right hip region. At the latter point a deep-seated para-articular abscess had to be incised. Headache occurred only upon active and passive movements. The sensorium was always entirely free. On the sixth day before death vomiting suddenly occurred again; the abdomen was very markedly distended, and coma was first noted twenty-four hours before death. Upon post-mortem examination, numerous metastatic abscesses were found in both lungs, with soft infiltration of the lower lobes of the left lung. A broad embolus was found in the spleen, and several smaller, fresh, still hemorrhagic emboli in both kidneys, side by side with which were several that had passed more or less into a state of suppuration. The liver was not changed. There were several fresh metastases in the heart. The small intestine was strongly distended, as a result of strangulation by axial rotation upon an abnormally long mesentery close to the cecum. The brain and its membranes were absolutely normal. In the left transverse sinus was a thrombus which was still firm at its upper end, but at the jugular foramen had undergone suppuration. The membranous wall of the sinus was slightly discolored and softened upon the bony side for a space of two centimeters, especially at the point where it had been necessary to lay bare the dura mater. The bony wall of the sinus showed, furthermore, a curious erosion and discoloration. In this case the sinus thrombosis had existed even before the chiselling, and the operation had not prevented the subsequent infection and disintegration of the thrombus.

Diagnosis of Septicemia and Pyemia.—As a rule, septicemia and pyemia are brought to mind by observing the *positive symptoms* already described. Continued fever in a case of suppuration, elevations of temperature either in the afternoon or at somewhat irregular intervals, suggest the beginning of septicemia. In pyemia frequent chills are noted on the temperature-chart. In addition to those characteristics already described, we must consider the following points:

When septicemia comes on within a comparatively short time after a wound has been inflicted, the local evidences of injury may have almost or quite disappeared. The surgeon should be extremely loath to consider a case of sepsis as *cryptogenetic* or *spontaneous* (Leube). Every effort should be made to discover the infection atrium by a careful search over the surface of the body for evidences of injury or its resultant inflammation. The natural orifices of the body are then to be examined, especially the fauces, the nose, and the ears. The term cryptogenetic is only to be used as a term of clinical convenience to indicate our inability to find the entrance point of the microbes.

Neglected wounds giving rise to sepsis often show marked signs of imperfect drainage, exuberant granulation, and cellulitis. In the later stages of sepsis, the injured tissues show almost no tendency to regenerate, and the granulations have a membranous covering of dirty gray material.

The distribution of pyogenic bacteria to the general circulation by way of the lymphatic system is proclaimed by the occurrence of *lymphangitis* and by temporary *hyperplasia* or even *inflammation of the regional lymphatic glands.*

When pyemia takes origin in thrombophlebitis of veins accessible to direct or indirect clinical investigation, symptoms corresponding to the obstruction of the blood-vessel involved will be noted. For example, in cases of thrombophlebitis of the cavernous sinus the eye bulges from the orbit and the lids are much swollen.

Local symptoms of metastasis are more frequent in pyemia, of course, since the secondary foci are susceptible of diagnosis if they are superficial or if, even when located in deep structures, they interfere with recognizable functions. Joint- and bone-inflammations, pleurisy, endocarditis, nephritis, etc., are recognizable with comparative ease when the lesions are well marked. But it must be remembered that many secondary points of pyemic inflammation must escape detection, since they may remain small and may not interfere seriously with any very marked function. This is especially true of emboli lodging in the lungs.

The secondary foci should be studied by *cultural methods* to determine, if possible, whether the bacteria are of the same species as those found in the primary lesion.

Enlargement of the spleen is common to all forms of sepsis, and that organ should always be interrogated by palpation rather than by percussion.

The *blood* in sepsis and pyemia has been studied frequently. Leukocytosis is present, the leukocytes being chiefly polynuclear, with neutrophile granulations. But the diagnostic value of leukocytosis is comparatively small, since an unimportant focus of suppuration anywhere in the body, even though entirely unassociated with the disease, may give origin to it. Nucleated erythrocytes are sometimes found in profound leukocytosis.

The discovery of *bacteria in the blood* is of importance in distinguishing sepsis. Canon insists that the blood should be drawn from one of the arm-veins, especially in post-mortem work, since such blood is much more likely to show the true state of the infection. The blood is withdrawn by means of a sterilized hypodermic syringe under aseptic precautions, and cultures and cover-slip preparations are made.

Other important and profound changes in the *composition of the blood* take place. Roscher tells us that the number of the red corpuscles is very much reduced, and proportionately, also, the amount of the residue left after evaporation. To a special degree the dry residue of the serum is reduced. These differences are less marked as the disease progresses. The hemoglobin is diminished and stands in direct relationship to the number of the red corpuscles. None of these changes, however, has been studied clinically in a sufficient number and variety of cases to put us as yet in possession of reliable diagnostic aids.

Many attempts have been made to utilize in a diagnostic way *the urinary findings.* The occurrence of the albumoses in the urine is noted in sepsis; but this is common to all the infectious diseases (Harris). Of course, toxemia is associated with sepsis, and signs of nephritis are always to be noted in the later stages of ptomaïn-poisoning. The fact

that the urine in many infectious diseases contains soluble chemical bodies of a toxic character lessens the value of a gross study of urinary toxicity as a diagnostic aid. Should we be able hereafter by chemical means to discover and distinguish the toxic bodies peculiar to different infections, we might be able to use in diagnosis the knowledge acquired.

The **differential diagnosis** of sepsis involves, first of all, the exclusion of sapremia. If autointoxication is excluded by causing the excretory organs to perform their functions actively, toxemia may be ruled out by a study of the local findings. Careful disinfection and removal of all putrefying material in the wound will enable us to put toxemia entirely out of diagnostic consideration.

Local suppuration is converted into septicemia by the transmission of bacteria to the blood and by the multiplication of the microbes there. If, then, the apparatus by which the germs are carried to the blood (regional lymphatic system) is demonstrably in a state of activity, and if cultures and stained preparations from the blood show pyogenic organisms on several occasions, the diagnosis of septicemia is assured. The temperature-curve, the urinary findings, and the local symptoms in the presence of free drainage will usually be determinative even without the blood-examination.

Typhoid fever and *miliary tuberculosis* are often difficult of exclusion. Hessler has prepared a table in which these diseases are distinguished from pyemia of otitic origin. It is quoted because it contains so much information in small space. The diagnostic points pertaining to the otitic origin of the pyemia are suggestive for the study of other forms of the disease.

SYMPTOMS.	OTOGENIC PYEMIA.	TYPHOID FEVER.	ACUTE MILIARY AND MENINGEAL TUBERCULOSIS.
Beginning:	Sudden, with severe head-symptoms — dizziness, vomiting, headache.	Begins with progressive prodromal symptoms, disorders of the general condition, only rarely (Liebermeister) with a chill and elevation of temperature to 40° C.	Sudden aggravation of an old bronchial catarrh, with dull headache and depression.
Running from the ear:	Has always preceded.	Accidental complication, occurs for the first time in the fourth or fifth week.	A complication of lung-tuberculosis.
Chills:	Frequently recurring after variable intervals, followed by sweats.	Rare.	Often at beginning a single chill, shiverings frequent in course of the disease.
Temperature:	Highly variable, atypical, going above 41° C.; often subnormal.	According to Wunderlich intermittent, slowly rising and falling. Absence of temperature-elevation rare.	At the beginning continuous at a moderate elevation, later hectic, at last subnormal, often like that of typhoid.
Sensorium:	For the most part not influenced in typical cases; disturbances as a result of headache, alternating with or following delirium.	Is increasingly disturbed at the end of the first week; later, muttering combined with delirium. Picking at the bedclothes.	Only slight delirium; later, sopor and coma.
Headache:	Severe, one-sided, variable near the ear and occiput. Increases with pressure on the neck (MacEwen).	Equally distributed over the head, without changing.	Dull, variable, equal on both sides.

Symptoms.	Otogenic Pyemia.	Typhoid Fever.	Acute Miliary and Meningeal Tuberculosis.
Vomiting:	Frequent, often recurring with the other signs of brain-irritation.	Rare.	Frequent, especially in meningeal tuberculosis.
Delirium:	Frequent, varying with other brain-symptoms, increasing in children to convulsions.	More bland.	Especially in meningeal tuberculosis.
Lung-symptoms:	Rapidly transitory, scarcely to be demonstrated, varying between bronchitis, metastatic abscesses with pleurisy, and pyopneumothorax.	Usually bilateral, bronchitic, in posterior lower portions.	Breathing disproportionately rapid, increased to orthopnea. Sounds normal or only large râles.
Metastases:	Especially frequent in the lungs, rare in the liver, in all organs of the body.	Not present.	Not present.
Appetite:	Good at first, then absent.	Slight.	Slight.
Tongue:	In mild cases not coated.	Dry, coated, protruded with tremor.	Usually remains moist.
Pulse:	Hard, full, increased frequency in chills and fever; disproportionately high in sepsis.	Hard and full, later soft, dicrotic, 80–100, parallel with temperature.	Disproportionately high; 120–150, soft and small.
Course:	Irregular in the intensity of the phenomena and in duration.	Characteristic temperature-curve over period of three to four weeks.	Irregular, lasting two to three weeks.
Abdomen:	Rare distention, occurring after the second week.	Frequently distended in the second week.	Not especially distended.
Roseola:	Lacking; but we find elevated red flecks not disappearing on pressure.	Characteristic roseola in second week, especially in the lower breast and abdominal region, not sensitive on pressure, often elevated.	Lacking.
Diarrhea:	In severe cases, toward the end, then watery, profuse, fetid.	Characteristic pea-soup stools.	Only in simultaneous intestinal tuberculosis.
Abdominal pain:	Frequent over lower spleen when metastases are present.	Ileocecal pain in the second week.	Usually lacking.
Spleen:	Almost without exception enlarged and palpable.	Constantly swollen and palpable.	As a rule, moderately swollen.
Icterus:	Frequent, in mild cases not with certainty.	Rare.	Rare.
Death:	In coma, usually by embolism of lungs.	In coma, with heart-failure.	In coma, or collapse with failure of lungs or brain.
Optic neuritis:	Often very clearly present, rarely septic retinal hemorrhage.	Not present.	Not present, choroidal tubercles frequently demonstrable.
Blood-examination:	Gives, when positive, different kinds of micro-organisms (streptococci and staphylococci).	Only typhoid bacillus.	Frequently tubercle bacilli.

Malaria is often to be differentiated from pyemia, since chills are common to both; but the careful study of the blood will disclose the malarial organism if it is present. Quinin is curative of most cases of paludism, but only slightly influences pyemia.

Acute malignant endocarditis and acute articular rheumatism are to be distinguished by reference to the positive findings in these diseases laid down in the text-books of internal medicine.

The occurrence of *metastases* in pyogenic disease is usually indicated by chills, temperature-variations, and local signs peculiar to the part involved. When metastases are found, the diagnosis of pyemia is

thereby established. The diagnosis of pyemia is not complete until the point is discovered at which the infection found its way into the blood. This is usually equivalent to the discovery of the vein undergoing thrombophlebitis.

Treatment of Septicemia and Pyemia.—The greatest triumph of surgery in which the present age rejoices is our recently acquired ability to prevent, in the majority of cases in which wounds are surgically inflicted, the infection of the exposed surfaces. In pre-antiseptic days, pus of certain characteristics was expected to form in almost all open wounds on the third or fourth day, and was called *pus bonum et laudabile.* It is now the elaborate and painstaking effort of every surgeon to prevent suppuration by bringing to his aid a well-organized corps of assistants provided with every needed appliance. To prevent suppuration in wounds is to avoid septicemia and pyemia; so that the prophylactic treatment of these morbid conditions may be summed up in the principle involved in aseptic wound treatment.

We must, moreover, not only avoid contamination by pus-microbes, but we must *prevent the lowering of the resisting power* of the individual by auto-intoxication. We must see that the patient's bowels move properly, that the kidneys are acting freely (as to excretion of urea), that no intestinal putrefaction is going on, etc.; and in diseases in which intoxications are present—for example, nephritis—we must either counsel against operation or redouble our efforts to prevent contamination. It has been shown experimentally that where a preliminary injection of the toxins of a certain bacterium has been made, the micro-organism will find lodgement in the tissues of the body somewhere, and grow freely when injected in numbers so small that without this aid they would inevitably perish.

Not only does the resisting power of individuals vary, but the resisting force of every human organism varies from time to time within wholly physiological limits. The influence of *hygienic causes* apparently the most trivial is often of vital importance. Thus it has been experimentally shown that rabbits may be made to inhale many tubercle bacilli without visible damage, so long as they are given free access to light and air; but if confined to dark places, they quickly die. In diseases in which the date of operation is elective, we may defer the procedure until the patient has been put into the highest physiological condition by proper hygienic and therapeutic measures.

Many cherish the hope that methods of *immunization* may be invented which will make it possible for us to protect our patients absolutely against pus-infection before the knife is used at all.

Even after infection has occurred, we think of aiding, so far as possible, those forces which repel the microbic invasion, and destroy or eliminate the micro-organisms from the body. This direct treatment of suppuration and its various modifications and consequences has been the ideal of medical investigators from the earliest times. We certainly know of no drug which will exercise a direct influence on this malady. But since the publication of Behring's researches on the diphtheria bacillus—following the proofs that an anthrax-immunity could be produced in certain lower animals—and since the "*serum-therapy*" of this disease has become an every-day fact, we have allowed ourselves to

hope that an immunity against staphylomycosis and streptomycosis (as the commonest forms of pyogenic infection) might be established in the human body by artificial means.

Extensive studies in this field have been published by several writers. Marmorek of Paris has boldly recommended the serum of animals immunized by a method of his own devising. His first effort, after choosing *streptomycosis* as the field of his activity, was to find cultures of sufficient virulence and to maintain that virulence. This he succeeded in doing, according to his statements, by passing ordinarily active cultures of streptococci through the bodies of experimental animals and by growing the microbes upon a culture-medium composed of two parts of human blood-serum and one part of meat bouillon. In this way he obtained a culture so "hypervirulent" that, according to his experiments, doses of as small a quantity as one one-hundred-millionth of a cubic millimeter were sufficient to kill a rabbit. With this potent virus asses, sheep, and horses were inoculated in increasing doses until they became highly resistant. Their serum remained toxic for other animals and for man for four weeks; but when this period had elapsed after the last inoculation, the serum conferred immunity upon animals when injected under the skin.

Without further delay for study and experiment, Marmorek began applying his serum to the treatment of human streptococcus-infections, and reported a series of injections with what he considers favorable results. Of 15 cases of puerperal infection treated, 7 with streptomycosis were cured, 3 with mixed infection with Bacterium coli died, and of 5 with mixed infection with staphylococci, 2 died. From this result he argued that mixed infections are not so favorably acted upon as the simple infection with the bacteria, for immunity against which the serum was prepared. In a series of 411 cases of erysipelas, the mortality declined from 5.12 per cent. to 3.4 per cent.; but to offset this slight reduction of death-rate Marmorek claims that the patients treated improved with wonderful rapidity after the administration of the serum, and that their sufferings were much ameliorated.

Many independent observers have tested the serum with results which are not yet conclusive. The critical and experimental review of Petruschky of the Koch Institute in Berlin is based upon the study of material (serum and cultures) from Marmorek's laboratory. Petruschky could not confirm the statements made in regard to the excessive virulence of the organisms, nor could he substantiate the reports of the Parisian experimenter in regard to the efficacy of the serum even in experimental animals.

At the present time, then, we have *no reliable antistreptococcic agent*, and Lubarsch even decides that, while our present knowledge embraces the established fact that in experimental animals an immunity to streptococcus-infection can be readily obtained, the blood-serum of the immunized animals contains neither antitoxic nor bactericidal powers.

W. Petersen of Heidelberg has attacked the less promising question of *immunity* to *staphylomycosis*. Petersen concludes that a transitory immunity to this disease exists when man has survived a severe attack of staphylomycosis, and he decides that when this immunity exists there are chemical substances in the blood-serum upon which depends the

resisting power of the organism. But he also recognizes the weakness of these bodies and their evanescent character. His own experiments having been interrupted, he suggests that a solution of the practical question of securing immunity for man may be found in the discovery of other methods of immunization, or that more active sera may be obtained from animals of species different from those upon which he experimented. It seems to him more likely, however, that the active bodies in the immunized serum already obtained may be separated by precipitation, and thus concentrated for use in the maladies of man.

Acting on the theory that the establishment of a *leukocytosis* is of benefit in combating pyogenic conditions, it has been proposed to bring about this form of activity among the wandering corpuscles in normal subcutaneous tissue by the injection of such irritants as oil of turpentine. This suggestion has been put into actual practice. The establishment, however, of even aseptic foci of inflammation does not find ready acceptance among modern surgeons.

The *elimination* of the micro-organisms by all proper means is to be encouraged; but the proposed plan of using phenacetin and other violent diuretics, as already mentioned above, does not seem wholly rational, since these drugs have other, and often dangerous, qualities. The skin may be made to do its full duty by the use of ordinary hygienic measures. The other emunctories should be kept active by the use of those remedies which, while stimulating excretion, do not interfere with the functions of vital organs.

The principle of elimination is involved in the plan of "washing the blood," or, as it is sometimes called, *hypodermoclysis*, in which large quantities (one to several pints) of normal salt solution are introduced under the skin. The fluid is, of course, readily absorbed and passes into the blood, while a corresponding activity of the kidneys tends to carry away the peccant material.

The *antipyretics* are usually to be avoided because they act as cardiac depressants (fever itself may be of utility in combating the infection), and because the temperature-curve gives important aid to the surgeon in determining the nature and severity of the disease. The most important medicinal agent in the active combat with septic infections is, according to Billroth, *alcohol*. It is borne by these patients in enormous doses and seems to exercise a favorable influence upon the course of the malady. It is administered in the form of wine (the stronger varieties) and the distilled liquors, brandy and whiskey. In egg-noggs, egg-flip, etc., we have a ready means of combining the agents with food. With peptonized milk and eggs the alcohol may be introduced in clysters when the stomach fails. *Digitalis* is reserved until the pulse weakens; but *strychnin*, pushed almost if not quite to the physiological limit, now enjoys a wide and apparently well-deserved popularity as a tonic stimulant. *Feeding* is just as important here as it is in typhoid fever, and it is the attendant's duty to see that a regular plan of feeding is arranged and adhered to. When the patient can no longer digest his food, it must be digested artificially before it is administered.

The influence of *elevated temperature* for the good of the patient cannot now be definitely decided upon. Yet there are not wanting those who maintain that many micro-organisms do not flourish as well at the fever-temperature, that the antibacterial forces of the body are stimulated by the heat, that elimination of toxins and even of the

bacteria is encouraged by the fever, and that the pyogenic cocci have a greater tendency to produce purely local reactions in the presence of pyrexia. Fever, then, is probably a beneficent condition, and is not to be combated *per se* as the inimical element of the disease.

The prophylactic *drainage* of pyogenic foci has for its object the removal of the infectious matter from the body under such technical conditions that granulations can speedily line the avenue of their discharge and place the abscess, so far as further entrance of toxins or microbes into the blood is concerned, practically outside the body. The principle embodied in the Latin saw, *ubi pus, ibi evacua*, is thoroughly incorporated in the teachings of modern surgery. The early discovery of the abscess and its immediate drainage will prevent most cases of septicemia and pyemia. It may be necessary to amputate limbs, to resect intestines, to extirpate a kidney or otherwise mutilate the body in order to substitute simple for complicated wound-relations. Too much hesitation in the performance of these operations may be the cause of the patient's death.

The opening of *secondary foci* should be similarly attended to; but, unfortunately, when the bacteria are already widely disseminated throughout the system or localized in inaccessible tissues, the course of the disease is only too frequently unchecked. Knowledge of this fact does not, however, excuse us from pursuing the pyogenic enemy to the last by freely draining its foci of reproduction wherever they can be reached.

In pyemia, quite as much as in the typical form of septicemia, it is of high importance to attack the primary site of disease, especially when symptoms point to the occurrence of *suppurative phlebitis.* When internal foci of inflammation are inaccessible we are, of course, powerless; but amputation is indicated when the extremities are the seat of an otherwise uncontrollable phlebitis. Extirpation of a puerperal uterus, whose veins are plugged by septic thrombi, is also indicated, and has been frequently practised.

Septic *pylephlebitis* due to localized suppurative peritonitis is more easily prevented than cured. Early removal of inflamed tissues (if their removal is permissible) and adequate drainage constitute the best safeguards.

The accessible intracranial sinuses have been, of late, frequently opened and freed of purulent detritus, and many lives saved. The technic of the operations and their details must be reserved for another chapter; but an abstract of one of Rushton Parker's cases[1] will illustrate the principles followed in operating upon cases of thrombophlebitis.

A young man twenty-five years old had suffered a rupture of the membrana tympani of the left ear on account of otitis media. He was attacked with sudden pain in the ear, and from the fourth to the ninth day of his sickness he suffered from daily chills, vomiting, imperfect sleep, and pyemic temperature. A fetid otorrhea was noted on examination, without swelling of the mastoid region, but with tumefaction and tenderness over the upper part of the jugular vein. Double optic neuritis existed, more marked on the right than on the left side. During the next two days four chills occurred. On the eleventh day of the disease a radical operation was undertaken, a skin-incision of seven or eight inches long being made over the internal jugular vein. The vein was thrombosed from the base of the skull downward to its junction with the facial vein; the facial vein also was thrombosed for

[1] Hessler, *Die Otogene Pyæmie.*

a short distance. Both veins were ligated with catgut, cut through at healthy points, and resected as far as thrombosed. The mastoid process was opened with hammer and chisel and the transverse sinus laid bare. It was found filled with green, stinking, putrefying fluid, and contained the loose end of the thrombus which plugged the jugular vein. The center of this thrombus showed upon section purulent softening. The thrombosed vein was cut away one inch from the bone and the rest scraped out with a sharp spoon. The transverse sinus was similarly scraped out, and, upon further probing, a hemorrhage occurred which was stopped by tamponade. Two days later the tampon was removed under narcosis, since pus had collected behind it. The lower half of the wound was sutured, and healed by first intention, while the upper half was tamponed with gauze. In the course of the next week the temperature rose several times to 39° C., once indeed to 40° C., but afterward the patient seemed to improve. After sixteen days he left the bed. Optic neuritis remained on the right side, but the subsequent atrophy improved after three months, when the mastoid process had cicatrized. The suppuration from the ear had ceased long previously.

CHAPTER VII.

ERYSIPELAS; HOSPITAL GANGRENE; TETANUS.

ERYSIPELAS.

ERYSIPELAS is one of the group of hospital pests which antiseptic surgery has not been able to banish from hospital wards. It is, however, seen much less often, and has been steadily diminishing in frequency in well-regulated hospitals. It may be defined as an acute inflammation of the skin, spreading along the surface, and rarely to the deeper parts, with a tendency to spontaneous recovery. It is accompanied by acute febrile disturbance, it may involve mucous membrane, it may recur. The name is derived from ἐρυθρός, red, and πέλλα, skin.

In the last century extensive epidemics of erysipelas visited Europe—France in 1750, and Great Britain in 1777. In this century epidemics are also recorded in these countries as well as in America. The epidemic in New England in 1842–43 was of a most malignant type. It spread from village to village in a manner unknown at the present time, and was accompanied by those deep suppurations seen only in the severest forms of phlegmonous erysipelas, not only the subcutaneous tissue, but even the muscles, being dissected away from their surroundings by the burrowing virus. Since that time, outside of hospital wards, we hear little of epidemics of this disease.

Etiology.—The cause of the disease is the Streptococcus erysipelatis. The single cocci are from 0.3 μ to 0.4 μ in diameter. They grow in serpentine chains, the links of the chains forming pairs of cocci, as in most forms of streptococci. The question of the identity of this organism with the Streptococcus pyogenes is still in dispute. The weight of authority at the present time is in favor of the identity of these organisms. (See Chapter I.)

The cocci are found in the capillary lymphatics of the skin and in the lymph-spaces chiefly (Fig. 44), but they are sometimes seen in the capillary blood-vessels and in the small veins also. They may be found even beyond the lines of the inflammation in parts as yet unchanged. Near the red border the growth of organisms is most active. The lymphatics are so crowded with them that the leukocytes are hard to find. Chains of cocci may be seen at this point in the adjacent connective tissue. The cocci are not found in the leukocytes in the lymphatics, but may be seen in the protoplasm of cells in the tissues. Nearer the center of the infected area the cocci have already disappeared. They are found in small numbers only in the vesicles. They do not spread freely through the circulation, though they may be found occasionally at a distance from the point of inflammation. The constitutional disturbance is therefore due largely to the presence of their toxic products. Though the appearance of the disease at distant points from the seat of entrance is proof positive

that the organism may be transmitted from one part of the body to another, yet the most frequent point of entrance is through the wound. This may be an operation-wound or some abrasion or minute wound so small as easily to escape notice. It is also possible that the organism may gain an entrance through the lungs or digestive tract, and an

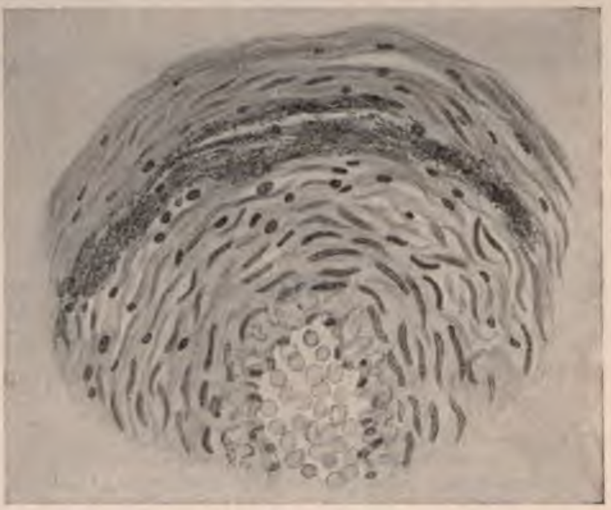


FIG. 44.—A small vessel near seat of inflammation, showing perivascular lymphatic crowded with streptococci.

intravascular infection may thus be produced. The healthy uninjured skin undoubtedly offers a sure protection against infection through that organ.

Erysipelas is a highly contagious disease. It has been spread by vaccination with unclean technic, and epidemics have thus been produced. Attention was first called to the close relationship of erysipelas and puerperal fever by O. W. Holmes. An excellent illustration of this was given in a certain hospital when an attempt was made to break up an epidemic of puerperal fever. The puerperal ward was converted into a skin clinic, in which erysipelas promptly appeared. Among the predisposing causes, the season of the year was at one time supposed to be an important agent. It is probable that the early spring, when the disease was supposed to be more rife, was influential only in that the general health of the patient is less likely to be vigorous than at other periods of the year. Age is probably a far more important factor. One rarely hears of erysipelas in children, although erysipelas neonatorum is still a familiar disease. Old people do not appear to be especially liable to it. Individuals broken down in health by long-standing malignant disease or other cachectic disease are undoubtedly more susceptible to infection of this kind.

Symptoms.—Constitutional disturbance usually begins before the local symptoms manifest themselves. This is usually in the form of gastric disturbance accompanied by pyrexia, which symptoms are known as prodromal symptoms. The tongue becomes heavily coated;

there is a sense of oppression in the epigastrium, with malaise, and possibly at night some delirium. Some enlargement of the lymphatic glands may be observed in the neighborhood of the wound. A day or two may pass before any change occurs in the appearance of the wound; but occasionally the general symptoms are so slight as to pass almost unnoticed, and then the earliest signs are seen in the wound itself.

By far the most characteristic feature of the disease is the inflammation of the skin. It is recognized by an increased feeling of tension in the wound, with increased heat, and usually with an itching or burning sensation. As exudation takes place, there are diffused redness and swelling, more or less uniform at the center, but at the edges showing a zigzag irregularity of outline, like the burned edges of a sheet of paper. There is a slight yellowish tinge to the part, and to the touch it feels more or less indurated. As the inflammation increases, minute vesicles are found in large numbers. Many of them fairly run together and form bullæ filled with a clear and slightly yellowish serum, which subsequently becomes turbid and at times purulent. The smaller vesicles soon dry and form yellowish or brownish scabs which furnish abundant material for desquamation. This material, containing as it does the organism, is undoubtedly a prolific source of contagion.

The local inflammation shows a tendency to spread in various directions. The outline continues to be well marked and is evidently due to the invasion of new lymphatic territories. The general direction of spreading is, when on the extremities, toward the trunk; when on the face, toward the scalp. It may meander over extensive surface, and the disease is then known as *wandering erysipelas* (*ambulans* or *migrans*).

At the end of three or four days the local inflammation resolves and adjacent regions soon become affected; occasionally the inflammation may appear at a long distance from the original focus of infection, and is then called "metastatic." It may return again to a part after having once left it. This recurring tendency is highly characteristic of the disease. Through all these changes the inflammation continues to remain superficial, and suppuration does not take place.

The disease usually lasts from one to two weeks and has a decided tendency to get well spontaneously; but even after apparent complete recovery has taken place, there is always danger of a relapse. Some patients are subject to what is called "*habitual erysipelas*," coming on at certain periods of the year or occurring always on certain parts of the body. In such cases there is often an elephantiasis-like thickening of the skin.

During the progress of the inflammation the lips of the wound, if it is in the early stages of healing, are swollen, and a thin seropurulent fluid escapes. In open granulating wounds there is comparatively little disturbance. The disease sometimes appears to exert a stimulating effect upon the healing process, the wound healing more rapidly than before. This is probably due to the absence of the virus in the capillaries of the granulation-tissue, and the extra blood-supply which they receive. The granulations are, however, occasionally infected,

and then lose their brilliant color and become dull and glazed. Hemorrhagic and necrotic spots may be found here and there. There is considerable sloughing in fresh wounds healing by first intention, and the healing process may be badly broken up under such circumstances. Pus may form and burrow freely. Secondary hemorrhage may occur under these conditions.

Pyrexia is usually well marked. The disease may be ushered in by a chill with a rapid rise of temperature which may reach 104° or 105° F. The temperature usually continues high, but varies in a most erratic manner, keeping pace with the local progress of the disease. After a prolonged attack there may be a subnormal temperature for several days, probably due to the feeble state of the patient.

Varieties.—**Phlegmonous erysipelas** is characterized by a spreading downward of the virus into the subcutaneous tissue. The infection is much more extensive than in ordinary erysipelas, and the local symptoms are consequently much more marked. The fever continues high, and is often typhoidal in character. It is not long before suppuration takes place. Free incisions give vent to a thin ichor, in which may be found shreds of sloughing tissue. Large sloughs eventually are discharged, resembling masses of wet blotting-paper. The pus burrows rapidly, and the skin for considerable distances is thus dissected off from the subjacent fasciæ. In rare instances, suppuration may extend more deeply still and invade the intermuscular spaces, but this type, fortunately, is rare. Even the periosteum and bones may become infected, and cases are recorded in which the joints have been involved and have become disorganized. In the extreme forms of this type large masses of tissue may become gangrenous. The approach of gangrene is ushered in by a dusky discoloration of the skin. Large bullæ, form filled with fluid having an offensive odor.

Some of the more rapidly spreading types of streptococcus-infection, such as are seen following infection of the hands, are closely allied to erysipelas, and have been by some authors grouped with this disease. The close resemblance of the two organisms is strongly suggestive of the similarity of the diseases.

Facial erysipelas has sometimes been called "idiopathic" erysipelas. Infection occurs through minute wounds or abrasions near the root of the nose. Starting from the bridge of the nose, the inflammation spreads laterally across the cheeks toward the ear, rarely involving the tip of the nose. It is said to have a preference for the right cheek. Its outline is usually well marked. It spreads gradually over one or both cheeks, and in severe cases involves the entire face, the ears, and eventually the scalp; less frequently it involves the neck. In its full development the swelling is great and the features are much distorted. The eyelids are edematous, and the nostrils are obstructed so that the patient is confined to mouth-breathing. There are high fever and a strong tendency to delirium, which is explained by irritation of the cortex of the brain rather than by congestion. This form of erysipelas may become phlegmonous, and orbital suppuration may occur with infection of the eye itself. Blindness is a not infrequent result of such complication. Septic meningitis may also be the outcome of such severe types of infection as this. But although the

swelling of the face may be most formidable and the delirium of an aggravated type, such cases may eventually terminate favorably.

Erysipelas neonatorum occurs through infection from the granulating surface of the stump of the umbilical cord. The disease is characterized by a blush about the navel with an extension of the inflammation to the thighs and genitals. There is considerable fever; gangrene or suppuration may occur as complications. The patient falls into a collapse and succumbs to the disease on the sixth to the tenth day.

FIG. 45.—A section of skin from scalp in a case of erysipelas: *a*, epidermic layer; vesicle-formation; *b*, cutis vera, leukocytes crowding the perivascular lymph-spaces; *c*, subcutaneous adipose tissue with lines of cellular infiltration; *d*, *e*, edematous connective tissue containing spaces distended by exudation: also perivascular lymph-spaces filled with leukocytes.

Erysipelas is found occasionally in the mucous membranes. In facial erysipelas there may be an extension to the pharynx and again back through the Eustachian tube to the external auditory meatus and the scalp. It may be traced as far as the lungs. Such combinations have been known as erysipelatous angina. If the glottis should become edematous, as it occasionally does, the result is nearly always fatal. The female genitals and the rectum are also occasionally the seat of erysipelas.

Pathological Anatomy.—The principal anatomical seat of the disease is the skin. The cells of the epidermic layer are much swollen or raised up into vesicles by fluid. There is much edema of the softer structure of the skin and subcutaneous tissue, as shown by the microscope (Fig. 45). The rich capillary network of lymphatics existing in the upper layers of the true skin, are crowded with leukocytes. Streptococci are found near the margin of the infected area, also in the neighboring parts, in the lymphatics, and in the subcutaneous tissue. When the growth of streptococci is unusually active, minute abscesses form and

are often absorbed without giving any external indication of their presence.

There are no organisms found in the blood-vessels, for they are usually speedily destroyed there, probably by the antitoxic properties of the blood-serum. The white corpuscles are greatly increased in numbers, and the red blood-disks assume a peculiar crenated appearance. Endocarditis involving the bicuspid and mitral valves may occur, and also pericarditis. A slight systolic murmur is frequently heard, which disappears with the erysipelas. The gastric disturbance is probably due to the general sepsis, as there are no local changes to account for it. Ulcerations of the small intestine are, however, sometimes seen. The brain and membranes are somewhat hyperemic and edematous. Suppurative meningitis, which is extremely rare, results from invasion from a phlegmonous inflammation through the orbit. Cloudy swelling of the spleen and kidneys and enlargement of the parotid gland are found.

Prognosis.—The prognosis of erysipelas is, on the whole, favorable. After a few days of inflammation there is a marked tendency to resolution, and this clinical fact should be borne in mind in estimating the value of any remedy. The disease varies greatly in its severity, but it may be said, on the whole, that it is less dangerous in itself than through its complications.

The repair of a wound is checked, and the recently cut surfaces are exposed to a widespread sepsis. There is always danger in such cases while the infections last. A large vessel may be opened, or a fatal edema or infection of the air-passages may take place. Severe erysipelas of the head or neck is always a source of anxiety for this reason, and also from the danger to the brain and its membranes.

Treatment.—This consists in the use of some local antiseptic application and internal medication. The constitutional treatment is at the present time supportive. Purgatives and other depleting measures should carefully be avoided, as the system needs strength to combat sepsis. For this reason alcoholic stimulants are valuable if used judiciously. They are needed chiefly in the aged and feeble and those broken down by long-standing disease. A nourishing and digestible diet is of the greatest importance, and it is probable that good nursing has as much to do with the successful treatment of erysipelas as any of the favorite methods. Alcohol had better not be given in facial erysipelas when there is much delirium, although delirium does not necessarily contraindicate its use. Large doses of tincture of chlorid of iron are supposed to have a beneficial effect upon the blood-corpuscle in this disease. It is given in dram doses every two hours. Quinin is also much employed. The drugs are frequently given conjointly; 5 to 10 gr. (0.33 to 0.66 gm.) of quinin in combination with 30 drops (2 gm.) of the tincture of the chlorid of iron, given 3 or 4 times a day, exert a powerful tonic action which is undoubtedly beneficial in the more chronic forms of erysipelas or during the later stages of an acute attack. Antipyretics have little influence on the temperature, and are contraindicated owing to their depressing influence upon the heart's action.

The number of salves and unguents recommended for this disease is legion. It is probable that some antiseptic drugs are capable of absorption through the skin and of exerting an antiseptic action upon the organisms. Among the best of these is carbolic acid. This may be applied in vaselin as a vehicle of the strength of 1 : 100 if a large surface is to be covered, and stronger when the area is small. Care should be taken that it is not absorbed in large doses. Gutta-percha

tissue should be applied over it as a protection. On small areas on the face an evaporating lotion of carbolic acid (consisting of ½ dram (2 gm.) of crystallized carbolic acid to 4 ounces (125 gm.) each of water and alcohol) may be applied on a piece of old linen. This lotion can be arranged to alternate with some form of antiseptic ointment. In erysipelas of the limbs, large antiseptic poultices of phenyl or other form of carbolic acid exert a moderate antiseptic action. Subcutaneous injections around the inflamed borders have not met with sufficient success to encourage their further use. In using carbolic acid, a careful watch should always be kept upon the urine. An indication of olive coloring should be cause for omitting the drug.

Isolation is important, as desquamation is always a source of danger, and it is probable that autoinfection may occur in this way. Many of the relapses are probably due to a re-inoculation. Special attention should therefore be given by the nurse to the care of the skin of the whole body. Frequent bathing with alcohol and water, or with boric-acid wash, will disinfect the scaling epidermis.

Frequent change of clothing is important for the same reason. If possible, the patient should have a complete change of all coverings, and should be removed to another room as a prophylactic against relapse during the period of convalescence.

Curative Influence.—During attacks of erysipelas it has long been noticed that chronic diseases of the skin often disappeared, such as tuberculous nodules, old ulcers, and sinuses that have obstinately resisted various modes of treatment. Old neuralgias get well, and even cancer has been known to break down and heal. The most beneficial effect has been observed on sarcoma. This was first noticed clinically by Tillman, and now has been employed for a long time with some success by Coley and others. (See *Sarcoma*.)

HOSPITAL GANGRENE.

This disease has disappeared, and is unknown to the present generation of surgeons in civilized countries. It is, however, highly probable that during war and famine it will reappear, and that it probably exists, perhaps unrecognized, in some countries where antiseptic methods are still unknown. It is desirable, therefore, that one who has seen many severe epidemics should record his experience, as there are not a great many surgeons at present living who are able to do this.

Hospital gangrene is a contagious traumatic disease, characterized by a diphtheritic wound-inflammation produced by poison, the precise nature of which is not yet fully understood (probably a streptococcus), and usually accompanied by more or less profound septic fever. The conditions favoring an epidemic of this disease are those which prevail during war time, when patients are crowded into hospitals with lack of proper means of treatment. The disease ran rife in the Crimean War, and also in the American Civil War. The conditions prevailing in the Confederate prison at Andersonville, South Carolina, furnish probably the most typical modern example of those conditions favorable for the development of such an epidemic.

The ground covered by the prison was about 15 acres in extent, but the space taken up by the various walls and the "dead-line" reduced the space to about 12 acres. This ground, which sloped toward the center on either side, was divided into halves by a small muddy brook which was defiled by the refuse and sewage of the prison. A morass of human excrement lined the banks of the stream. There was no protection to the prisoners except caves built by them. The greatest number of men accumulated at any one time is said to have been 35,000. In the month of August, 1864, there were 31,678 prisoners in the stockade, and the number of deaths in that month amounted to 2993. During the months of July, August, and September, 1864, there were 208 deaths from hospital gangrene in Ward No. 5 of the Andersonville Hospital. It is probable that there were a large number of deaths from gangrene following bites from insects or supervening on ulceration from scurvy, etc.[1]

No bacteriological reports have been made of the virus of this disease, and no suitable opportunity has offered since the advent of bacteriology. It seems highly probable from the mode of action of the virus, and from such imperfect histological reports as have been received, that the organism is a streptococcus, and possibly an organism which, by frequent culture under certain conditions through several generations, is able to produce the pathological phenomenon of hospital gangrene. It may be for some such reason as this that we do not see isolated cases, as in all other traumatic infective disease. The period of incubation is uncertain, varying from twenty-four hours to three days.

The principal forms are the ulcerating, the pulpy, and the diphtheritic—names given to indicate the appearance of the surface of the wound. The local constitutional symptoms are far more pronounced in the pulpy form. This variety includes all the graver cases with extensive and deep-seated loss of tissue.

One of the earliest symptoms observed in a wound, indicating the approach of the disease, is a change in the color of the granulations. In the era when epidemics of hospital gangrene flourished, dressers were warned to watch carefully for the "grayish look" of the granulating surface. If this appearance became more marked, it was evident that the superficial layer of the granulation-tissue had become necrosed, and that a "rind" or "membrane" had formed, giving the surface a diphtheritic look. This is known as the *diphtheritic form.* The secretion of the wound is at first diminished, and later it is increased and becomes more liquid than usual, quickly saturating the dressings. The edges of the wound are somewhat inflamed and thickened and indurated. As the rind separates, sloughs of considerable size are revealed. The wound assumes a crater-like appearance, and the edges of the wound appear as if gnawed by some rodent. When the process is arrested by treatment, the sloughs are cast off, healthy granulations appear, the congested edges of the wound resume their natural thickness and color, and the cicatrizing process is resumed.

Ulcerating Form.—Here the formation of a rind does not occur. The granulations have an unhealthy appearance, are paler than usual, and lose their plump, exuberant character. On closer inspection, minute extravasations or exudations are seen, and when these points break down, small cup-shaped ulcerations appear on the surface of the granulations. The edges of the wound begin to recede, and the wound becomes larger. Sometimes there is only a tendency of the wound to enlarge without any marked organic changes—a condition analogous to ulceration. At other times, the wound gradually becomes discolored, and the discharge is thin and streaked with blood and has a foul odor (ichor). The interior of the wound has finally a dirty-greenish hue. The edges of the skin are frequently quite

[1] Warren's "Surgical Pathology."

PLATE 6.

Ulcerating hospital gangrene.

unchanged in appearance, and one is often surprised to find them deeply undermined with gangrenous pockets.

The progress of the disease is not rapid, and the breaking down and enlargement of the wound and the formation of sinuses burrowing in different directions may be an affair of several weeks. In this way an amputation-stump may become fairly riddled with pockets and sinuses extending up between the muscles or beneath a fascia. The different phases of phagedena are well portrayed by this type of gangrene. There is not much constitutional disturbance at first, but the temperature shows marked fluctuations corresponding with the local spread of the infection. In a prolonged case of several weeks there is a corresponding amount of septic fever, which, although it does not develop into a true septicemia, tells more or less severely upon the patient and causes emaciation and prostration.

The **pulpy form** is the most acute and grave type of the disease. The local reaction is very pronounced, and it is evident from the first that a most virulent infection has occurred. The integuments of the wound are swollen and tender, and a thin gleety discharge oozes from between its lips. The inner surface of the wound becomes edematous and sphacelated, and the tissues are extravasated with numerous small effusions of blood. The surface is soon changed to a dirty-gray or greenish mass of putrefying tissue. The secretion from the wound becomes enormous, and has a characteristic fetid odor. The edges of the wound become everted, and the spongy mass of putrefying tissue wells up between them. The edges of the white skin marked with blue veins are a deep red and extremely sensitive. These changes take place very rapidly, and a wound may increase to four times its size in from twenty-four to forty-eight hours. In the meantime, the system begins to sympathize, and true septicemia may be developed, which may carry the patient off. As the infection advances, no tissues are spared: the muscles are laid bare and the nerves are dissected. The fasciæ are more resistant. Articulations may be laid open, and even the bones may not escape necrosis. The great swelling which takes place is often deceptive as to the amount of tissue which has been lost. This is obvious after the sloughs have separated and the coverings of the wound contract. Although septicemic, the patients are fully alive to the sensitiveness of the wound, which at times appears to be hyperesthetic. The pain attending the dressing of wounds in some cases is so great that few men possess the fortitude to go through the ordeal. Secondary hemorrhage is a not infrequent complication of this type of gangrene. Ligature of the artery at the point of election may be followed by gangrene of the new wound and a later hemorrhage from this point. Erysipelas is also an occasional complication of the disease.

Diagnosis.—There is occasionally some difficulty in recognizing the disease in its early stages. Mechanical or chemical irritation may produce changes in the appearance of the granulation. This may result from irritating dressings or from the presence of a foreign body in the recesses of the wound or sinus. In aged patients a superficial slough will often form on the surface of a rind caused by the coagulation of the slowly secreted exudation. Occasionally bed-sores will

counterfeit closely the appearance of this disease, both in the sloughing character of its surface and in the rapidity with which it grows.

Prognosis.—The prognosis of the disease is very variable. Isolated cases are usually of a subacute or chronic type; it is only in epidemics under unusually unfavorable conditions that the malignant types of the disease are observed. In the "Surgical History of the War of the Rebellion," the number of cases of hospital gangrene recorded was 2642. Of these cases, 1142 were fatal, making a mortality of 45.6 per cent. In one of the more recent epidemics which occurred in the barracks at Berlin, the mortality was only 6 per cent.

Treatment.—In order that local treatment may be of any avail, the agent employed should be brought directly in contact with the freshly diseased tissue. The dead tissue on the surface must then be cut away, and all sinuses must be relentlessly laid open, so that any particle of infected tissue may be subjected to the action of the antiseptic drug. The actual cautery has always been a popular mode of treatment. It is said to be less painful than applications of perchlorid of iron. Cold applications applied subsequently relieve the pain. An antiseptic poultice alternating with an antiseptic bath would favor the separation of the sloughs and prevent relapse. Nitric acid in full strength was used by Southern surgeons during the Civil War. "The acid should not merely coagulate and alter completely the gangrenous matters, but also come in contact with the sound parts" (Jones). For such severe measures the patient should be placed under the influence of an anesthetic.

Keen used acid nitrate of mercury, preferring it to nitric acid, as it caused less pain and saved time by enabling the surgeon to dispense with an anesthetic. The slough also separated more quickly. Goldsmith advocated strongly the application of pure or fuming bromin. It spreads readily in all directions, and its action is almost instantaneous. In milder cases an acid wash containing hydrochloric acid was used for many years at the Massachusetts General Hospital. It can be applied on gauze.

℞ Potass. chlor.,	℥ss (16 gm.);
Acid. hydrochlor.,	ʒj (3.75 c.c.).
Misce et adde	
Aquæ,	℥viij (236 c.c.).

Most of these remedies would be abandoned at the present time for modern antiseptics. It would be necessary, however, to curet and cut away all gangrenous tissue with the same care as was employed formerly. Hydrogen peroxid would be eminently useful in aiding in the destruction of the dead organic matter. It could be followed by an application of carbolic acid, 1 : 20 or 1 : 40. All recesses of the wound should then be stuffed with iodoform gauze. An amputation for hospital gangrene of a stump was successfully performed by a German surgeon in 1870. The antiseptic agent used was "phenyl water."

All cases should be immediately isolated, and the ward in which the case occurred should be thoroughly cleansed and disinfected. A chronic case which has obstinately resisted local treatment will often improve rapidly after a complete change of room, of bedding, and of clothing.

TETANUS.

The name is derived from τείνειν, to stretch. Tetanus is an infectious disease, generally traumatic in origin, characterized by painful tonic contraction of the muscles, beginning with those of the jaw or the neck, and affecting progressively the muscles of the trunk and limbs. It is accompanied by convulsive paroxysms and an irritation or inflammation of the nerve-centers in the upper portion of the cord. It is due to the presence of a bacterial virus in the blood and tissues.

The Bacillus tetani was discovered in 1885. It is a long, slender rod, in one end of which a spore forms, distending the cell into a "drumstick" shape (see Chapter I, Fig. 4). It is one of the most marked types of anaërobic bacteria. The organism is found principally in the tissues near the wound of entrance, but it has not been satisfactorily demonstrated in either the blood, the internal organs, or the central nervous system. It is assumed that the organisms manufacture at the point of entrance, or that there is introduced with them, an extremely active poison which disseminates itself throughout the body. The relation of the toxin to the organism and to the system in tetanus is, according to the latest authorities, not yet clear.[1] The tetanus bacilli are found in large numbers in the soil, particularly in garden soil, in the dust and sweepings of our streets and dwellings, in crumbling masonry, in putrefying fluids, and in manure. Their presence in these localities is, however, always uncertain. It often happens that particular geographical regions are favored by its presence. It is only by experimental inoculations that its presence can definitely be established in any locality. Owing to the anaërobic nature of the organism, the bacilli are unable to grow upon small and superficial wounds, except in rare instances. Punctured wounds lodge the organisms deep in the tissue, a soil better fitted for their growth.

Etiology.—Among the predisposing causes of tetanus may be mentioned age. It is peculiarly fatal to children under ten years of age. The disease is said to be rare in later life. Meteorological changes have been said to favor tetanus. Certain changes of weather after battles have been repeatedly noticed as preceding epidemics of tetanus. In tropical countries the disease appears to be much more common. The gravity of the wound does not appear to have any influence upon the severity of the disease.

All cases of tetanus are traumatic in origin—that is, it is highly probable that the poison is introduced through some wound, however slight, whether of the skin or mucous membrane. The old term "idiopathic tetanus" had better be abandoned. The term seems, however, to show that many cases of tetanus do occur when there is no appreciable wound. Cases of tetanus following simple fracture have been reported; also infection through so slight an injury as a hang-nail.

Varieties.—Tetanus is divided into acute and chronic forms, the former being almost invariably fatal, and cure often occurring in the latter variety. Puerperal tetanus and trismus nascentium are varieties usually considered as a group by themselves, but they are in reality not distinguished etiologically from traumatic tetanus. Head-tetanus or tetanus hydrophobicus presents certain clinical peculiarities which justify placing it in a class by itself.

Acute tetanus usually has a period of incubation of about one week. The first symptom is a stiffness of the muscles of the neck, coming on in the morning after a comfortable night's rest. It is usually attributed to a cold, but during the day the stiffness extends

[1] Rose, in his exhaustive work, "Der Starrkrampf bei Menschen," 1897, pronounces it an unsolved riddle.

to the muscles of the jaw, making it difficult for the patient to open his mouth. There is as yet no discomfort, but the contractions soon become painful, and owing to their power and frequency it becomes difficult even to swallow liquids. The masseters are now felt in a state of rigid contraction as hard as iron, and with well-marked borders. The muscles of the back of the neck are next involved, and the head is thrown backward by their contraction. Before the close of the day all the muscles of the back are affected, producing opisthotonos. If the hand is now passed down to the abdomen, the parietes are felt as firm and rigid as a metal plate. There is already retention of urine, which when drawn off with the catheter appears to be abundant and of a normal color. The muscular spasm, at first clonic, becomes now continuous or tonic. Attempts to swallow cause pain and distress. After a sleepless night the patient is found the next morning well advanced in the stage of full development of the disease. The locking of the jaws is as complete as before, and nearly all the voluntary muscles of the body except those of the upper extremities are involved. The arms may also be involved, but only to a partial extent. The lower extremities are rigidly extended. The muscles of the face are affected; the eyelids are seamed, the nostrils and the mouth are puckered in a peculiar way, while its corners are drawn back by a contraction of the cheeks. The eyes are drawn in and partly closed, and occasionally there is strabismus (Risus sardonicus). The patient is now extremely sensitive to disturbance of any kind; attempts to move him in bed, to administer nourishment, or to pass the catheter bring on a paroxysm of convulsive action of the most painful character. The violence of muscular contraction has even been sufficient to produce rupture of the muscle.

Meanwhile the patient lies as still as possible, usually upon his side, with his head drawn rigidly backward and with a deep hollow in the curve of the spine. His mind is perfectly clear, but the rigidity of the muscles of the jaws and cheeks does not enable him to articulate clearly. The spasm of the sphincters renders voluntary movements of the bowels or the bladder very difficult.

During the height of the disease—that is, on the third or fourth day, exhaustion becomes marked from loss of nourishment and sleep. Short periods of sleep may be obtained by drugs, during which there is some relaxation of the muscular spasm; but no complete remission ever occurs, and the patient is soon startled out of a disturbed slumber by renewed convulsive movements. There is usually little fever; the temperature-curve is in no way characteristic in this disease, but as death approaches, and even post mortem, there may be hyperpyrexia. There is occasionally found after each convulsion a tendency to free perspiration, which may become quite a characteristic feature of the case. It acts probably as a means of dissipating the heat produced by the active and extensive innervation of the muscular fibers.

In the last stages of the disease the mind continues clear, delirium is extremely rare, and the patient is fully sensible of the agonizing spasm to which the slightest noise or disturbance in the sick-room gives rise. In tropical climates the disease may run a still more acute course, death supervening a few hours after the onset of the attack.

In **chronic tetanus** the period of incubation is longer, the first symptoms making their appearance during the third week. The order in which the muscular system is involved is the same as in acute tetanus, and the spasms may be of great severity, but there are periods during which the patient experiences relief from muscular contractions. These periods gradually become longer, and soon an entire day may pass without a relapse. There is great prostration, particularly when the disease is prolonged by frequent relapses. Cases of six weeks' and of two months' duration are occasionally seen. Yandell reports one case in which the duration of symptoms was two hundred and forty days.

Head-tetanus or **tetanus hydrophobicus** occurs after injuries in the region of distribution of any of the twelve cranial nerves; consequently it is chiefly confined to the head. It is characterized by spasm of the pharyngeal muscles and paralysis of the facial nerve, as well as trismus, and occasionally by tetanic contraction of the muscles of the neck and abdomen. Rose explains the paralysis of the facial nerve by compression in the petrous portion of the temporal bone, due to swelling of the nerve. According to Bunner, the reported symptom of facial paralysis is due to an error of observation.

Cephalic tetanus occurs usually after a wound in the face, such as may result from a blow from a whip-stock or the fist in a street-brawl. The paralysis of the facial nerve almost always occurs on the same side as that in which the injury is received. There is usually marked paralysis of the lower lid on that side. A marked feature of this form of tetanus is the difficulty in swallowing, which symptom has given rise to the term *tetanus hydrophobicus*. This symptom, however, is not always present. Head-tetanus is not always fatal. In a collection of 24 cases of head-tetanus, 7 recovered, and of these 6 were cases of chronic tetanus.

Pathological Anatomy.—There is little change in the appearance of the wound. Occasionally there is a slight blush about its edges, and sometimes there are evidences of lymphangitis. Wounds of the extremities are more likely to be followed by tetanus than wounds in other regions, probably because they are exposed to punctured wounds, the foreign body carrying in with it dirt which may contain the virus. A rusty nail thrust into the sole of the foot is a not infrequent cause of the disease; the organisms are thus carried deeply into the tissues, and have an opportunity to develop there undisturbed by oxygen or suppuration. There is sufficient evidence to show that the virus acts with more or less power chiefly upon the nervous centers of the cord and medulla, but the data do not yet seem to be sufficient to establish the fact of multiple neuritis or irritation of the trunks or branches of the nerves over and above that of other tissues to which the virus may be conveyed. Evidences of inflammation of the brain and meninges are wanting, but a number of observations point to inflammation in the upper portions of the cord.

Diagnosis.—The disease is not difficult to recognize in the fully-developed stage, but in the nature of the early symptoms there may be some doubt. Stiffness of the jaws may be due to inflammatory affections of the mouth or the teeth, or to abscess of the cervical

glands, and also to rheumatic affection of the temporomaxillary articulation. Occasionally a hysterical contraction of the muscles of the jaw may occur.

The question of death by tetanus or by strychnin has been raised in medico-legal cases. In strychnin poisoning there is usually no lock-jaw; there is hyperesthesia of the retina, and objects seen are colored green. During a paroxysm the mouth foams and the teeth lacerate the tongue. There is also spasm of the muscle of the limbs and trunk. The occurrence of muscular spasm is irregular, and depends upon the frequency and size of the dose. Tetany affects chiefly young persons, and consists in tonic spasms of various groups of muscles, most frequently those of the upper extremities. The attacks are short and more or less localized, and Trousseau's symptom, seen in no other convulsive disease, is always present. This symptom consists in the peculiarity that pressure upon the nerve-trunk leading to the group of muscles affected always brings on a characteristic attack.

Hydrophobia is said to resemble tetanus owing to the difficulty of swallowing in the two diseases. There is, however, no convulsion in hydrophobia. The hydrophobic paroxysm is due to an inhibition of the respiratory nerve-center and the natural movements of distress which this calls forth. The clinical pictures of the two diseases present striking contrasts to one who has seen them both.

Prognosis.—Acute tetanus is one of the most fatal of diseases. In chronic tetanus the percentage of mortality is very much lower. According to Hippocrates, the patient dies on the third, the fifth, the seventh, or the fourteenth day; if he survive this period he recovers. According to the tables of the "Surgical History of the War of the Rebellion," of 337 deaths, 287 occurred during the first week of the disease; and of those occurring on the eighth day there were but 7 deaths. In Yandell's 415 cases, there is a marked falling-off of deaths on the fifth day, when there were but 11 deaths, from which time the percentage steadily diminished. Rose states the mortality of early cases as 91 per cent., and that of late cases as 48 per cent.

Treatment.—Among the internal remedies which have enjoyed a more than usual reputation may be mentioned Calabar bean, chloral, cannabis Indica, curare, amyl nitrite, quinin and opium. Yandell places chloroform at the head of the list in cases of acute tetanus, but also makes the significant statement that when tetanus continues fourteen days recovery is the rule and death the exception, apparently independent of the treatment.

Calabar bean, when given in small doses, relieves the muscular contraction. Poncet advises from 1 to 1½ gr. (0.065 to 0.1 gm.) of the extract given every four hours, or from 15 to 20 drops (0.92 to 1.25 c.c.) of a 1 per cent. solution may be injected subcutaneously.

Chloral seems to be most efficacious in chronic tetanus; it relieves pain and prevents spreading of the muscular spasm and recurrence of the convulsions. It appears to act by diminishing the reflex excitability of the nerve-centers. In large doses (from 100 to 200 gr. (6.5 to 13 gm.) a day) chloral will relieve muscular spasm in acute tetanus, but it does not appear to have any appreciable effect upon the mor-

tality. Chloroform may be administered by inhalation. Its action is decidedly sedative, but not so enduring as that of chloral.

Opium does not appear to enjoy the popularity of chloral and chloroform. Large doses are required, and the digestive disturbance caused by the drug is a contraindication to its use.

Bromid of potassium may be used in connection with chloral, or in the convalescent stage as a substitute for that drug, but it is altogether too mild a remedy to produce any appreciable effect in the more active stages of the disease.

The great "sweating," which is so characteristic a symptom of tetanus, has suggested the use of warm baths and of other diaphoretics as a means of imitating nature's method of relief. It is possible that some of the toxins may be eliminated in this way.

So far as **local treatment** is concerned, it is important to mention that the bacilli, being anaërobic, lie deep if in a state of activity. Punctured wounds should be thoroughly laid open and disinfected. A free discharge from the wound should be favored. It is probable that the old-fashioned flaxseed poultice has warded off tetanus in former times by inducing suppuration in the wound. A dry dressing which seals up a small opening is a source of danger. The most careful antisepsis and asepsis do not always prevent the occurrence of tetanus. According to Rose, no treatment of the disease is of so much value as the local treatment. This is shown both by experiment and by clinical experience. It destroys the bacilli and prevents the renewal of their toxic products.

Serum-therapy.—Both Kitasato and Behring have contributed largely to the introduction of a serum. They produced immunity in certain animals by the injection of cultures of the tetanus bacillus, whose activity had partially been destroyed by the addition of trichlorid of iodin. The serum of animals thus rendered immune could be used on other animals as a protective or curative agent. The exact nature of the immunizing substance is unknown, but has been called "Antitetanin." It was found that mice inoculated with fragments of tissue containing tetanus spores could not be saved even by the use of 50,000 times the ordinary immunizing dose. This would seem to show that a great deal depends upon whether we have to deal with the toxins or the micro-organisms themselves in a given case.

In 1838 252 cases of tetanus collected gave a mortality of 50 per cent., and 912 cases collected in 1889 gave a mortality of 44 per cent. Rose, who is perhaps one of the greatest living authorities on tetanus, has collected (1897) 54 cases treated with serum with a mortality of 40 per cent. The great variation in the severity and duration of cases of tetanus renders statistics of little value in judging whether serum does any good or not. There is no proof that serum has any influence upon the acute type. As regards the lighter cases, many other factors enter into the cure. There are dressings and operations, etc., but even in these cases Rose does not see anything conclusive to prove the value of serum. He says: "Die serum therapie hat mehr Hoffnungen als Leistungen." He concludes: "In man there is no absolute proof of recovery due to the serum. Local surgery has given the best results, especially when combined with narcotics to relieve the irritation of the nerve-centers, and supportive treatment to overcome the exhaustion."

Tetanus antitoxin is generally obtained from the serum of a horse rendered immune by increasing doses of tetanus toxin. Horse-serum becomes thus antitoxic after two or three months of such increasing toxin injections. Tetanus antitoxin is usually employed as a blood-

serum. A dry powder or scales are sometimes used. This is prepared by evaporating the serum to dryness over sulphuric acid. One gram of the powder is equal to 10 c.c. of the original serum. The serum may be precipitated with alcohol. The dried precipitate thus obtained is the material used by Tizzoni.

Dose of the Serum.—This is based upon the immunizing power, which should be in the proportion of 1 : 1,000,000. One cubic centimeter of serum should be a sufficient dose to protect 1,000,000 grams of guinea-pig, or 2000 guinea-pigs each weighing 500 grams, from the minimum fatal dose of tetanus toxin when injected eight to twelve hours afterward. The dose varies according to the weight of the individual, and also according to its use as a prophylactic or curative agent.

The curative treatment, as regards the amount and frequency of injections, is based upon the urgency of the symptoms and the subsequent improvement. The shorter the period of incubation and the more acute the case the larger the dose. It should always be given as early as possible.

The following table gives a general idea of the dosage of the antitoxin:

	Prophylactic Dose.	Curative Dose.
Serum	5–10 c.c. Repeat in two weeks.	20–40 c.c. = initial dose. 10–20 c.c. at subsequent injections every twelve to twenty-four hours p. r. n.
Dried material	1 gram. (Dissolved in boiled water.)	2–4 grams = initial dose. 1–2 grams = subsequent doses.

Children should be given about one-half the adult dose. No ill effects are said to be produced by the serum. The antitoxin should be administered subcutaneously. The serum should be kept in a cool place and should never be heated.

The serum treatment should be used in connection with the other forms of treatment. Later experience has proved the necessity for intravenous rather than subcutaneous injection of antitoxin, as assuring more rapid absorption, and the dose should be proportionate to the strength of the serum. Behring considers a dose of 500 units essential, and in serums having a strength of 1 unit to the cubic centimeter, as much as 500 cubic centimeters must therefore be given as the initial dose. The intracerebral injection of the serum, which has been recently practised, has not as yet established its value.

There is no disease in which the comfort of the patient should be studied so carefully. Before active symptoms have set in, the patient should be placed alone in a room so situated as to be quite free from disturbance. Officious nursing should be avoided. Nourishment and stimulants should be given in a form to sustain strength while producing as little irritation to the throat as possible. Chloroform may be given in order to administer nourishment by the stomach-tube if necessary (Rose). Many acute cases may thus be made chronic. Every day added to the patient's life after the first week of the disease increases greatly his chances of recovery.

CHAPTER VIII.

HYDROPHOBIA; ANTHRAX; GLANDERS; ACTINOMYCOSIS; MADURA-FOOT; SNAKE-BITE; INSECT-BITE.

RABIES.

MANY **synonyms** for this disease exist; of these, the most important are Hydrophobia, Lyssa, Furor, Rabies, Rabidity; Wuth (*Ger.*); Rage (*Fr.*).

Rabies is a disease of man and certain other mammals which is communicated from one individual to another by the infection-bearing saliva through freshly infected wounds.

The **history** of the disease is a long one, and, on account of the characteristic symptomatology, is less complicated by confusion with other maladies than is the case with the accounts of certain other disorders. Hippocrates did not describe the disease in his works; but Aristotle, a half-century later, recognized it in the lower animals. Celsus gave a good account of rabies in the first Christian century.

For centuries, no very essential progress in the knowledge of the disease encouraged its observers, so that many medical men began to lose faith in its existence as a separate nosological entity. Bosquillon in 1802 advanced as a positive belief the idea that hydrophobia was a mere chimera. Experimental inoculation researches a few years later dispelled this notion forever, and the more recent extensive researches of Pasteur on its etiology, prevention, and cure, have made hydrophobia a comparatively well-studied disease.

Distribution and Frequency.—Since almost all the mammalian animals are susceptible to the disease and can transmit it to man, and since man is attended in all parts of the habitable globe by these animals, the disease is distributed over the whole world. No land is known to be immune to rabies, since both hot and cold climates have their records of the disease. Australia is said to be free of the disease, supposedly on account of a six months' quarantine to which all dogs are subjected before admission to the island.

Besides dogs, cats, wolves, horses, swine, and cattle, which are the most common agents for the transmission of infection, foxes, jackals, asses and mules, sheep, rabbits, and man are also responsible. Dogs, of course, cause the disease most frequently; but not only on account of opportunity, since the saliva of infected dogs is thought to be usually more virulent than that of other animals. Epidemics of rabies are usually traceable to one originally infected animal which has transmitted the disease to others. The cases of so-called spontaneous rabies are doubtless due to the original infection of dogs or cats by rats or other animals living in hiding from man. Hoegyes explains the frequency of outbreaks in summer by the fact that man is at that season more exposed to infection by an outdoor life, often in close association with the lower animals.

The number of cases annually occurring is sufficiently indicated by the fact that, between the years 1887 and 1895, 14,296 cases were treated at the Pasteur Institute in Paris; while in the Buda-Pesth Institute, from April 15, 1890, to Dec. 31, 1895, 4961 cases applied for aid. Of course, many of the cases applying for treatment doubtless had been bitten by animals not actually rabid; but even deducting these, the number is large.

Etiology.—Opportunity for infection, of course, counts for much in the causation of the disease. Those individuals who, like farmers and laborers, are much in the open air and are associated with the domesticated animals furnish the greatest contingent of cases. Nearly twice as many males are infected as females, for the same reason. Children, unable to

escape from infected animals or to protect themselves when attacked, are much more frequently bitten than their elders. The part of the body wounded is of etiological importance. The limbs are protected by the clothing, which tends to prevent deep bites and to wipe off the virus from the teeth of the animal before they enter the flesh of the victim. Besides, the face and other parts of the head being located nearer the centers of the nervous system and of the circulation, afford better opportunities for the virus to reach the vital parts.

Although experimental research has not been successful in establishing definitely the biology of the infectious agent in rabies, it has done much to determine the conditions under which infection takes place, the life history of the disease, and above all it has demonstrated, through the brilliant researches of Pasteur and his pupils, the fact that an immunity against the disease may be established and, as we shall see, may be utilized in the practical treatment of the disease. Before Pasteur's time, it had been shown by several investigators that the disease is really transmitted by the infected saliva. Galtier in 1879 published the results of experimental studies proving that the disease as it occurs in dogs may be transmitted to rabbits, affording a ready means of determining the virulence of the saliva obtained from dogs suspected of rabies, especially as the period of incubation in rabbits is much shorter than in dogs. It was Pasteur, however, who showed that the virus of rabies exists in the central nervous system and is most concentrated in the medulla oblongata. The inference was quickly drawn by Pasteur that the inoculation of the virus into the central nervous system would be more rapidly and certainly followed by the disease than if the subcutaneous method were employed. Thus was found a ready and sure means of producing the disease, in almost every case, by injecting the triturated spinal cords or medullas of infected animals into the subdural spaces of other animals susceptible to the disease. Intraocular injections are almost as certain in their results. Applying the injected matter directly beneath the sheaths of the principal nerve-trunks is a valuable experimental method. When the infectious matter is introduced into the subcutaneous tissue, it is carried centripetally to the central nervous system along the nerve-sheaths. Having reached the central nervous system, it is then redistributed to the periphery by way of nerve-sheaths.

The gross **anatomical findings** in rabies are insignificant in proportion to the great gravity of the disease. The vascular engorgement seen is probably due to the struggles of the victim during the stage of excitation. Even microscopically nothing characteristic of rabies can be found. Certain degenerative changes are noted in the cells of the central nervous system, especially the multipolar cells of the anterior horns. Cellular infiltrations in other cases are noted in the gray substance of the cord. The pathologist must therefore depend for his diagnosis rather upon the results of inoculation experiments, and for this purpose the brain and spinal cord may be reserved.

The **symptoms** of the disease **in inoculated animals** are of especial practical importance on account of their bearing on the infection of human beings attacked by such animals. The form of rabies occurring in 80 or 85 per cent. of the cases in dogs is characterized by three stages—an initial stage, a stage of irritation, and a stage of paralysis. Incubation in dogs inoculated by bites varies much in duration, but on the average is sixty days. Temperature-elevation is noted as

the first sign of the disease, lasting a half to three days. The dog then becomes dull, sad, unfriendly. The appetite becomes poor and later abnormal, the dog biting, chewing, and even swallowing paper and trash of various sorts.

The irritation or rabid stage follows upon the initial stage by somewhat gradual exaggeration of the preceding symptoms. This is the stage of madness. The dog is more excitable, distrustful, and snappish. His voice is hoarse, and he howls rather than barks. Anxious to escape from confinement, he runs away aimlessly when released, snapping and biting at every man or animal in his way. Three or four days pass before the excitation gives place to paralysis of the exhausted nerve-centers. The dog appears weak, runs unsteadily, breathes rapidly and irregularly; his tongue hangs out of his mouth, from which drips a bloody, foamy saliva. Paralysis is soon followed by death. In the minority of cases (15 to 20 per cent.) the stage of excitation is so abbreviated as to be unnoticed, or is even altogether absent. The animal is first considered ill when the symptoms of weakness or even of paralysis are observed. This is known as the quiet form of rabies. When well-marked signs of rabies are present, the disease is almost invariably fatal in either of these forms.

It will thus be seen that the **diagnosis of rabies in the dog,** while usually easy, may require the observation of a competent veterinary surgeon to distinguish it. In the absence of such aid and in doubtful cases the dog may be killed, and the brain and spinal cord removed as nearly aseptically as possible. The specimen is sealed up aseptically and transmitted immediately to the expert in rabies. By him the medulla oblongata will be rubbed up with physiological salt solution, and a portion of this material injected into the subdural space of a rabbit's brain. If rabies virus is present, it will with certainty cause the disease to appear in the inoculated animal.

The **symptoms of rabies in man** correspond well with those of the disease in dogs. The incubation stage may be as short, in rare cases, as thirteen or fourteen days. Usually death takes place between the twentieth and sixtieth days. The incubation may in rare instances be very long—six, thirteen, fourteen, twenty-two months. It is of interest from a therapeutic point of view that the incubation period is apparently lengthened by depressing influences. The wounds seem to heal about as rapidly as ordinary wounds exposed to similar conditions. It is only severe contusion, pus-infection, and cauterization that delay healing. A local reddening of the scar seems to occur during the initial stage, associated with such signs of nervous disturbance as centripetally radiating pains, burning, tickling, and other evidences of paresthesia. Anesthesia and hyperesthesia, also, at times give evidence of dissemination of the virus along the nerve-trunks. The *stage of nervous excitation* is indicated by mental excitement, spasms of the respiration and deglutition muscle-groups, and this stage is in turn succeeded in man by the stage of exhaustion and paralysis. Before the onset of active symptoms, the patient seems melancholy and depressed; then he becomes restless and eager to walk about. Such moods of depression may be succeeded by short periods of joyous excitation, which are again followed by depression.

In the *stage of excitement*, or hydrophobia, respiration becomes difficult, sighing, and anxious, and the bystanders note with especial horror the patient's inability to drink on account of spasms of the pharyngeal muscles. As the disease progresses, even the sound of running water, or the suggestion of it, will superinduce these spasms. The patient, dreading the onset of the contractions, fears to attempt drinking, hence the term hydrophobia (from Greek words meaning "water" and "to fear"). Spasms of other muscle-groups commonly occur, and hypersensitiveness of the various sense-organs is often seen. Hallucinations may thus arise. Consciousness remains undisturbed, except during the exacerbations, almost to the end of life. The horror of the disease is thus fully appreciated by the unfortunate victim. The flow of saliva is increased, and, as it is the chief vehicle of infection, much care must be exercised to prevent the attendants and bystanders from being inoculated. In delirium the patient may eject the saliva, almost as if he had the intention to infect others. It is a popular error that hydrophobic patients imagine themselves to be dogs, and bark, bite, and snap at the attendants. Elevation of temperature, priapism, and satyriasis are observed.

While the stage of excitation lasts from one and a half to three days, the final stage of paralysis may, in man, be altogether wanting or may last but a few minutes. It is usual for the patient to lie relaxed for two to eighteen hours before death. In man, as in lower animals, a paralytic form of rabies exists, in which the active symptoms of the disease are but slightly marked, while the paralytic phenomena appear with especial prominence.

The **diagnosis** of rabies often involves the exclusion of hystero-epilepsy, tetanus (in which spasms of the muscles of the throat often occur), delirium tremens, epilepsy, sunstroke, poisoning—especially by datura stramonium—and brain-tumors.

The **prognosis** in wounds inflicted by rabid animals is variable. In only 15 or 20 per cent. of the cases does the disease break out at all; but when the disease is well established in a human subject, it almost inevitably destroys life.

Treatment of rabies by prophylaxis, therefore, is especially important. This involves decreasing the number of dogs in communities by taxation, controlling dogs by registration, by the use of muzzles, and by excluding them from certain public places.

When persons are bitten by animals known or suspected to be rabid, the animal should either be killed at once or confined and carefully watched for pronounced signs of the disease. In the former case the central nervous system is removed, and, parts of it (medulla) having been rubbed up with sterilized salt solution, the material thus obtained is injected into a rabbit's subdural spaces. The disease will thus be speedily transmitted to the inoculated animal, giving us a well-nigh infallible diagnostic test. But one should not wait until this test is completed before immunizing the person bitten. The patient is usually sent to a branch office of the Pasteur Institute. Such laboratories are located in all civilized countries.

Immunization is effected by successive injections of virus which has been weakened in virulence in various ways. Gradually the strength

of the virus is increased until the maximum is reached, when the patient is declared insusceptible to the action of the infectious agent. In this way more than 50,000 persons were treated between 1885 and 1895, with astonishingly good results. The inoculations themselves are entirely harmless. The method employed at the Parisian Pasteur Institute, where the virus is diminished in activity by drying the spinal cords from which the emulsion is made, is, for wounds of the extremities, as follows:

Day of Treatment.	*Period during which Medulla has been Dried.*	*Quantity of Emulsion used.*
1	14 days, 13 days	3 c.cm. (♏48).
2	12 days, 11 days	3 c.cm. "
3	10 days, 9 days	3 c.cm. "
4	8 days, 7 days	3 c.cm. "
5	6 days	2 c.cm. (♏32).
6	5 days	2 c.cm. "
7	5 days	2 c.cm. "
8	4 days	2 c.cm. "
9	3 days	1 c.cm. (♏16).
10	5 days	2 c.cm. (♏32).
11	5 days	2 c.cm. "
12	4 days	2 c.cm. "
13	4 days	2 c.cm. "
14	3 days	2 c.cm. "
15	3 days	2 c.cm. "

When wounds have occurred about the head, the treatment given is somewhat stronger—the emulsions of stronger virus being administered earlier.

ANTHRAX.

Synonyms.—Pustula maligna, Carbunculus contagiosus, Woolsorters' disease, Splenic fever; Milzbrand, Hadern-Krankheit (*Ger.*); Charbon (*Fr.*).

The **history** of anthrax in olden times is complicated by the confusion with it of various cutaneous maladies associated with a tendency to destruction of the skin. But its more modern history is a more profitable study, worthy of especial consideration because this was the first disease affecting man to receive full bacteriological study. No other infectious process has been so frequently the object of research, and the results of these researches, conducted by the greatest masters of modern methods, have afforded paradigms for the investigation of numerous other diseases of the same type.

Pollender found vibrio-like bodies in the blood of anthrax animals as early as 1855. Two years later, Branell found, besides these rod-like organisms, small vesicular and dust-like bodies. Branell was the first to make inoculation experiments with a view to determining the infectious character of these bodies; but it is to the persistent and courageous work of Davaine, appearing in numerous communications to the Paris Academy of Sciences from 1864 to 1873, that we owe the real foundation of our modern doctrine of anthrax, and hence of the wound-infection diseases in general. It was he who first showed that the rod-like bodies of Pollender and Branell were living organisms. He contended that these bodies were the cause of the disease, and showed that the blood of affected animals, if it contained these bodies, was capable of transmitting the disease. Absolute demonstration of the truth of his convictions could not be made by Davaine for the lack of culture-methods, which were then unknown, and the greatest living authorities disputed his theory until

F. Cohn and Robert Koch proved the spores to be a link in the continuity of life in the anthrax microbe. Koch, Pasteur, and Klebs finally added absolute proof by the inoculation of pure cultures.

Etiology.—Referring the reader to the chapter on Bacteriology for a technical consideration of the Bacillus anthracis, we pass to a consideration of the etiology of the disease, an elementary knowledge of which is essential to our study.

Splenic fever is a disease common to man and certain of the lower animals. It is through association with infected animals or their carcasses, as a rule, that man is infected.

The bodies of animals, usually cattle, horses, sheep, etc., dying in pastures or marshy lands are often neglected by ignorant farmers, and the anthrax bacteria are scattered as the bodies decompose. The spores of the microbe may remain for long periods inactive in the buried or partly covered flesh, and may be distributed to a distance by flood-waters. In this way, whole pastures and water-courses may become infected, and other animals grazing over the land contract the disease by contact with the spores. Even if the body of the animal is buried just beneath the surface, the bacteria may be brought up by earth-worms, snails, and beetles. The older recommendation to bury the bodies of animals dead of anthrax at least one meter deep is best replaced by the rule that such bodies should be destroyed by fire. Infected districts can be purified only after considerable time by thus destroying the carcasses and by confining susceptible animals to other feeding-grounds.

The animals susceptible to anthrax are chiefly the herbivora, especially sheep and cattle. Algerian sheep, however, possess a certain immunity against the disease. Horses are less frequently affected; but it is said that the disease occurs among Russian horses, oftentimes in epizoötic form. Wild animals of the deer and antelope families are occasionally subject to the disease. Such rodents as guinea-pigs, mice, and rabbits are quite subject to the disease, but the varieties of rats are unequally susceptible. Infrequently dogs, cats, foxes, and hares are attacked. Ducks, pigeons, and crows are but slightly susceptible, while chickens are more readily attacked. Cold-blooded animals are quite resistant.

The disease is transmitted to man from infected animals; and it facilitates the study of this part of the etiology to premise that the bacteria gain admission by way of skin-injuries, by inhalation of infected dust, and by the ingestion of infected foods.

Those who are engaged in handling hides are likely to infect small abrasions of the hands or of the face. Wool-sorters in England, handling wool from all parts of the world, are often affected with anthrax of the respiratory passages. Butchers are liable to infection of cuts. Veterinaries are inoculated while treating the disease. Farmers sometimes contract the disease in handling the living animals or their carcasses. Pathologists have frequently been infected while making post-mortems of experimental animals dead of the disease. The story is related by Lubarsch that one young pathologist contracted the disease by smoking, while conducting an autopsy on a cock which he had killed with anthrax. The cigar, frequently handled and replaced in the mouth, was doubtless the carrier of the microbes. Rarely is the disease conveyed by infected foods.

The atrium of the microbe in man is usually an abrasion of the skin, but the bacteria can enter by the lungs and by the intestines without the occurrence of wounds. The injuries of the skin may be produced by the infection-bearing object, or the inoculation may occur upon a wound already made in the absence of granulations. Flies are said to transmit the disease (Koch), and the bristles from which brushes are made have frequently carried the microbe. Surgeons have repeatedly conveyed the infection by using imperfectly sterilized catgut from sheep suffering from splenic fever.

The **pathological anatomy** of anthrax in man consists essentially in necroses and serous, serofibrinous, and seropurulent inflammations, as well as hemorrhages (Lubarsch and Frank).

The most generally known lesion of splenic fever in man is the initial lesion at the site of infection when the skin is first invaded—the "carbuncle" or "pustule." A small translucent vesicle appears at the site of inoculation, turning to a bluish-red color, and by bursting is converted into a small, irritable, itching tumefaction. It is characteristic of this little ulcer that, while its edges are elevated, its center is depressed and of a dirty-black or purple color, due to necrosis of the tissues. The neighboring skin is often reddened and infiltrated. When the central scab is raised, there exudes a thin fluid which contains anthrax bacilli in greater or less numbers. This characteristic appearance often suffices to clinically identify the disease, and to suggest an examination for the specific agent of the disease.

Microscopical examinations show active inflammation going on in the affected skin, the corium and papillary layer being infiltrated with a sanguinolent, cellular exudate. Although the bacteria can penetrate into the deeper layers of the corium, they lie chiefly in the external portions of the corium and in the papillary bodies.

If the primary lesion occurs in the intestinal canal, the general appearance is much like that of the cutaneous lesion, a similarity which in the main is borne out by microscopical examination.

In the case of primary pulmonary infection, the spores are inhaled with dust and become arrested in the bronchial tubes and alveoli, where they develop. They are then observed in the connective tissue and the lymphatic spaces of the organ. Inflammation, edema, and the exudation of a bloody serous fluid in the pleural cavities are commonly observed (Ziegler).

Should the bacteria grow in the circulating blood, they are found in the most distant parts of the body, and in especially great numbers in the capillaries of the abdominal viscera. In the lower animals the tendency is for the disease to spread by way of the blood, while the primary lesion is by no means so characteristically developed as in man. Death occurs, usually, as a result of intoxication by the poison characteristic of the bacillus, the old theory of a mechanical occlusion of capillaries important to the vegetative functions having been abandoned as untenable.

The **symptoms** and **course** of anthrax in man depend to a great extent on the point of entry of the disease. In the form beginning with a cutaneous lesion, the face and head are most frequently attacked, then the upper extremities, the neck, the trunk, and, finally, the lower extremities. While a single carbuncle is usually observed, numerous instances are recorded in which two or four lesions were observed in simultaneous evolution. The period of incubation, lasting usually two or three days, is very imperfectly characterized by malaise, dulness, belching, indigestion, and perhaps a slight febrile movement. Only two or three days more are consumed after the appearance of the pustule before the disease extends beyond the purely local stage, since the lymph-glands of the affected region become enlarged and painful, and the skin over them becomes edematous. The fever, meanwhile, has

become higher, the dulness greater, and the gastric symptoms more pronounced.

The disease may now terminate in recovery or in extension of infection and death. In the first instance, the scab over the carbuncle falls off, a clean granulating surface is left, and the wound heals by the usual process of epidermization. When death ensues, it follows as a result of general infection. Death may occur early—even in two or three days, when the infection has been especially violent. Usually at least four or six days elapse. The gastric symptoms are pronounced, the vital powers are greatly depressed, and pains are felt in the head and limbs. Chills are followed by high fever. In many cases, though not constantly, the spleen is enlarged. The appearance of the carbuncle is such as to indicate no healthy reaction; the skin about it is blue, cool, and doughy to the touch. The general weakness increases, although the consciousness often remains unclouded to the end. The severity of the general symptoms increases rapidly, the vomitus is bloody, the extremities become cool, the pulse continuously weaker, thinner, and scarcely perceptible. The patient complains of great dyspnea, a profuse cool sweat appears, the voice weakens, the temperature falls, and death results under increasing somnolence and gradual loss of consciousness. Sometimes delirium, coma, or convulsions close the scene (Koranyi).

A second form of the disease, known as *malignant edema* (œdème charbonneux), begins as a doughy, almost translucent swelling, most frequently observed over the upper eyelid. The swelling is very great, causing the eyeball to disappear completely. General infection may take place from this primary focus of the disease, and its outcome is usually fatal.

In the gastro-intestinal form of the disease death usually occurs. It is ushered in with a prodromal stage often lasting but a few hours. Weakness, headache, vertigo, and vague pains are followed by the active stage of the disease, in which complete anorexia, great thirst, nausea, and vomiting occur. The abdomen becomes distended and tender, the pulse weak and thready; cold sweat appears, and convulsions are often noted. Perforation of the intestines may lead to death by peritonitis.

The **diagnosis** of splenic fever is not difficult to make where the typical carbuncle is observed, leading at once to a search for the anthrax bacillus. Malignant edema may be recognizable only by exclusion when the imperfect development of the primary carbuncle does not supply a clue. Intestinal anthrax cannot be diagnosticated in the absence of an anamnesis referring to the ingestion of infected meat or milk. Intestinal and pulmonary anthrax are, before death, scarcely demonstrable without the discovery of the bacillus. This organism must be sought for by culture-methods wherever its presence is suspected.

The **prognosis** is least grave in the cutaneous form of anthrax, where the local lesion is well marked and lends itself to local therapeutic measures. Malignant edema gives a less favorable outlook, and cured cases are referred to as rarities. So far as the cases are recognizable, the intestinal form of anthrax is very fatal. But of all forms, the pulmonary type gives the highest death-rate—50 per cent.

according to Eppinger; 75 to 80 per cent. as estimated by British writers.

The **treatment** by prophylaxis is of the highest importance—first by burning the bodies of all infected animals, and second by sterilizing, where possible, the various products of unknown animals which may carry the contagion—*e. g.*, hair, wool, bristles, hides, catgut.

Pasteur's method of immunizing sheep by the inoculation with mitigated virus has been found practicable in limiting the spread of the disease in Australia and in France, and is worthy of further application among susceptible domestic animals.

Cauterization of the primary lesion by a large number of agents has been tried with varying success. But a better plan is the excision with the knife, as suggested by Fournier. The incision is to be carried through perfectly healthy tissues. Bryant and Baker cauterize the newly exposed surface. Verneuil extirpated with the thermocautery.

In case excision is unavailing in stopping the disease or cannot be employed, quinin in stimulating doses is to be tried. Leube recommends 30 gr. (2 gm.) of the hydrochlorate with 15 gr. (1 gm.) of carbolic acid, divided into ten doses, to be given in one day. Ipecacuanha is recommended for the intestinal form, followed by calomel. It is to be hoped that an antitoxic serum will soon be provided for this disease, as has been experimentally attempted by Emmerich. Symptomatic remedies are, of course, indicated in the systemic forms of anthrax as elsewhere.

GLANDERS.

Synonyms.—Malleus humidus, Farcy; Morve, Farcin (*Fr.*); Rotz (*Ger.*). Glanders is an infectious disease of horses and other mammals, transmissible to man, and characterized pathologically by the deposit of nodular lesions in various tissues. The disease has been recognized as a separate nosological entity for a long period, but its specific causative agent, the bacillus of glanders, was not identified until its recent discovery by Löffler.

In the horse the disease produces lesions and symptoms described by Youatt as follows:

"The earliest local symptom is a nasal discharge, which consists of an increased secretion, small in quantity, and flowing constantly. It is of an aqueous character, mixed with a little mucus. It is not sticky when first recognized, but becomes so afterward, having a peculiar viscidity and glueyness. The discharge soon increases in quantity, and in the advanced stages becomes discolored, bloody, and offensive. On the other hand, the discharge may continue for many months, or even for two or three years, unattended by any other symptom, and yet the horse be decidedly glandered. The glands under the jaw soon become enlarged, and are generally observed on the same side as that on which the nostril is affected; the swelling at first may be somewhat large and diffused, but this subsides in a great measure and leaves one or two glandular enlargements, which become closely adherent to the jaw-bone. The mucous membrane of the nose becomes of a dark-purplish hue, or almost of a leaden color—never the faint pink blush of health, or the intense and vivid red of usual inflammation. Spots of ulceration will probably appear on the membrane covering the cartilage of the nose; these ulcers are of a circular form, deep, and with abrupt and prominent edges, and become larger and more numerous, obstructing the nasal passages, and causing a grating or choking noise in breathing. The disease extends upward into the frontal sinuses, and the integument of the forehead becomes thickened and swollen, causing peculiar tenderness. The absorbents about the face and neck now become implicated, constituting farcy; these enlarge and soon ulcerate. The absorbents on the inside of the thigh, and then the deep absorbents of both hind legs, are next involved, causing the parts to swell to a great size, and to become stiff, hot, and tender. The constitutional symptoms are loss

of flesh, impaired appetite, failing strength, and more or less urgent cough; the belly is tucked up; the coat is unthrifty and readily comes off. The animal soon presents one mass of putrefaction, and dies exhausted."

Man is exposed to infection from diseased animals, the infectious matter being blown out of the nostrils of the animal into the eyes, nose, or mouth of the individual, or the disease may be contracted by bathing in water in which brushes or harness have been cleaned after having been used on infected animals. Cavalrymen, horseshoers, hostlers, veterinaries, and butchers are most exposed to infection.

Course and Symptoms.—The disease may run a course in man which is either acute or chronic. In the first form it often simulates rheumatism or typhoid fever. Beginning with malaise and rheumatic pains in different parts of the body, an elevated temperature soon develops, and with it, if the infection atrium is upon a visible part of the body, nodules appear at and near the site of infection. The skin may be quite generally attacked with a pustular eruption which leaves ragged, dirty ulcers. These ulcers may spread and coalesce, and phlegmonous infiltrations may spread away from them. Lymphangitis and lymphatic adenopathy are often seen. The primary seat of disease may be in the upper air-passages or even in the bronchi, but this localization is not so common in man as in the horse. The secondary foci of the disease, due to the transmission and localization of the bacilli by the vascular apparatus, are distributed in much the same way as the secondary foci of suppurative inflammation, to which the individual lesions bear a close resemblance.

While the acute form of glanders is fatal in a few days or two or three weeks, the chronic form has a fatal outcome in only about half the cases, and then only after from two months to one or more years. In the chronic form of the disease the resemblance of the pathological processes is in favor of syphilis and tuberculosis. These secondary deposits are noted not only in the internal organs but in the muscles and the subcutaneous tissues.

The **morbid anatomy,** according to Baumgarten, is that of a disease standing midway between abscess and tuberculosis. Says Preisz:

"The first beginning of the nodular formation is the appearance of epithelioid cells with signs of karyokinesis, exceptionally also with several nuclei. These epithelioid cells arise from the fixed cells of the connective tissue, of the vessels, or of the parenchyma involved; from the border of the nodule there begins later an infiltration by wandering leukocytes, which, in consequence of the segmentation and breaking up of their nuclei, are more nearly related to pus-corpuscles than are the leukocytes of tubercles; finally there follows softening and breaking down of the nodule, while at its periphery proceeds the process described."

The **diagnosis** of glanders in the well-marked cases occurring in those whose occupations are suggestive of exposure to infection is by no means difficult; but in the acute cases affecting persons not usually associated with the lower animals, especially when the infection atrium is concealed, and when the symptoms resemble those of rheumatism or of septic infection, the diagnosis may be doubtful or even erroneous. In the chronic cases in which localization of the lesions is not typical, doubt or confusion may again occur.

To aid in diagnosis we have several valuable signs, some of which are conclusive. Of these are, in the first place, the discovery and identification of the Bacillus mallei. This demonstration is proof posi-

tive of the disease. Strauss has proposed a quicker method of reaching a conclusion—by injecting the discharges into the peritoneal cavity of male guinea-pigs and noting the swelling of the testes which invariably occurs within a few hours. Unfortunately for this test, the swelling occurs also after the injection of certain non-pathogenic micro-organisms.

When the tuberculin test for tuberculosis was introduced, efforts were instituted to obtain a similar test for glanders. These efforts culminated successfully in the discovery of *mallein*, a product consisting of the toxins of the glanders bacterium as obtained from pure cultures grown on various artificial media. The reagent is injected hypodermically in quantities corresponding with the strength of the preparation and with the size and general condition of the subject. When a suitable dose is thus administered to an animal or a man affected with glanders, a thermal reaction occurs in from 75 to 90 per cent. of the cases. The rise in temperature must be, in horses, not less than 2° C. to be determinative. We thus have a valuable addition to our means of determining the existence of the disease in its latent chronic forms, especially in horses.

Treatment in this disease also becomes largely a matter of prophylaxis, and the mallein test gives us abundant aid in the stamping out of the contagion. Since horses which have been tested with mallein are in no way injured, the reagent may be freely applied to all the horses in a country and to all imported animals, all the infected animals may be destroyed, and in this way the disease may be almost or quite stamped out. Man is thus best protected.

When the disease is once contracted, it usually proves fatal in the acute form. No adequate treatment has yet been proposed, although methods by the use of the serum of immunized animals have been tried. In the chronic forms of the disease, in which the death-rate is not so high, more may be accomplished by surgical treatment. The ulcers are treated antiseptically, especial pains being taken to destroy the bacteria in the discharges. Abscesses must be promptly opened, if possible with the thermocautery, in order to prevent further infection by way of the lymphatic system. Of course, general symptoms will be treated according to ordinary indications.

ACTINOMYCOSIS.

Actinomycosis is an infectious process superinduced in man and in the ox by the micro-organism known as *actinomyces* or ray-fungus. In the ox the disease is commonly called *lumpy-jaw*. In Germany the fungus is called *Strahlenpilz*, and the disease *Strahlenpilz-krankheit*.

The **history** of the disease as a recognized entity is very short. Although Bollinger was the first to prove the connection of the ray-fungus with the lumpy-jaw of cattle, Langenbeck (1845) and Lebert (1857) had pictured the fungus-granules long before. Israel in 1878 described "characteristic mycoses" in man, which have since been recognized as cases of actinomycosis. Ponfick first demonstrated the actinomycotic infection in such cases in man, and established its pathology upon a sound pathological and clinical basis. With this beginning, surgeons in all parts of the world proceeded to a careful study of the

disease with such enthusiasm that in 1892 Illich of Vienna was able to collect 421 cases occurring in man. Every surgeon of experience is now familiar with the malady, and while actinomycosis cannot be considered a common disease, it is far from being rare.

Minute Anatomy.—The bacteriology of actinomycosis is of great interest, especially because of the difficulties encountered in artificially cultivating and in classifying the micro-organism, and in deciding whether the varying forms of the microbe belong to one or more species. For a discussion of this part of the subject the reader must be referred to the chapter on Bacteriology. We may say, however, that the production of sulphur-yellow granules is characteristic of the morbid process. These granules are composed of masses of actinomycetes adherent together. The presence of these masses in the tissues gives rise to much proliferative reaction on the part of the tissues, which is expressed in the deposit of leukocytes, the multiplication of the fixed tissue-cells, and the formation of giant cells. The kernel-like mass of bacteria is thus soon surrounded by active granulation-tissue—the usual concomitant of chronic inflammation. As is also the case in chronic inflammation, this newly-formed connective tissue may contract at a later time and cut short the activity of the micro-organism. But a single nodule of this kind is not likely to be formed; many such masses usually lie side by side. These, by coalescence, produce indurations as extensive as the diffusion of the bacteria permits. These masses may "heal out" by penetration of the connective tissue into the midst of actinomycetes. But, on the other hand, degenerative processes in the center may occur, and a purulent material form, which, increasing in quantity by the coalescence of many nodules, may be forced into distant tissues by the pressure of muscles, etc., and convey the disease to distant structures. Fibrin is deposited in considerable quantity in the invaded tissue.

Should this process occur in the midst of bone-tissue, the osseous structure will be destroyed in the immediate neighborhood of the disease, while the bone undergoes hyperplasia about the periphery.

There is no controversy about the hyperplastic activity excited by the ray-fungus; but all are not agreed as to its pyogenic properties. Israel is the champion of the pyogenic theory. Bostroem, with whom Eppinger agrees, believes that at first an acute inflammation occurs, which soon becomes a chronic process of a reactive proliferative character, and as a result of which the exudate undergoes disintegration. Hobell, whose views are essentially the same, calls attention to the fact that actinomycosis is to be counted as one of the forms of pseudotuberculosis. Aschoff maintains the specific pyogenic power of the organism, and calls especial attention to the metastases of the disease, with which pus is usually associated, as evidence in favor of this view. Of course, no one denies that pus is usually associated with all forms of the disease as it occurs in man; but the pus is generally ascribed to a mixed infection with other micro-organisms.

The **gross pathological anatomy** of the disease is everywhere associated with chronic indurations, with softening and liquefaction, and with the resulting sinuses.

About the head and neck, which are favorite sites of the disease, the lower jaw and cervical fascia are frequently affected. The soft parts are usually thickened and indurated, and here and there soft spots occur, which eventually break down and result in sinuses, discharging a thin watery pus, in which are usually seen the small sulphur-colored granules. The cervical fascia is often attacked by the disease, which then gives the neck a brawny hardness that may become very extensive in area. The lymphatic glands are not, as a rule, extensively affected. After a time the liquefaction-process brings about the formation of sinuses opening upon the skin, when the massive enlargement diminishes somewhat in size. In the

ox the tongue is often affected, and attains a considerable size and great hardness. In the neck the skin is frequently attacked, the induration occurring at irregular intervals, throwing the integument into folds or waves of irregular enlargement.

Although the ray-fungus is capable of producing a superficial bronchitis unassociated with any other pulmonic lesions, the *lungs* are, as a rule, affected with a well-marked phthisis, which usually runs a course much like that of tuberculosis. In the *abdomen* the disease usually takes origin in the appendix or cecum, about which swellings form, which may be confused with carcinoma, but which at last soften with the discharge of pus. Sinuses open either upon the skin or into the intestines or bladder.

The **atria of infection,** the **symptoms,** and the **course** of actinomycosis were studied by Israel under the subdivisions: (1) Head and neck; (2) chest; (3) abdomen; (4) brain; and (5) the skin. Although the actinomycetes have not been studied in their natural habitat outside the body, it is known that infection usually occurs as a result of contact with various grains. Infection of the structures of the head and neck takes entrance through the mouth and throat. The old notion that those engaged in the care of actinomycotic animals furnish the chief contingent of cases is now no longer tenable, although it is undisputed that some cases of the disease give this history. The majority of cases are infected by contact with infected grain. A most striking illustrative instance is that of Bertha, in which the disease took origin in a wound of the posterior wall of the pharynx. In the wound was found a grain covered with actinomyces, which was sticking in the wound. A number of patients have testified that they were in the habit of chewing the grains or the straw of wheat, barley, or other cereals. In the Leipzig Pathological Institute a case of pulmonary actinomycosis examined post-mortem was carefully studied and a grain found in the lung-cavity. It was supposed to have been aspirated into the lung. The cases of intestinal actinomycosis are thought to be caused by swallowed bacteria.

FIG. 46.—Actinomycosis of the cheek (Illich).

FIG. 47.—Actinomycosis, cervical type (Illich).

The atrium of infection in the faciocervical form of the disease is often a decayed tooth, in which an infected grain has occasionally been found. The papillæ of the tongue and the follicles of the tonsil are excellent saccules for the retention of the infection-bearing body. Infected meat, either raw or imperfectly cooked, has been suspected of bearing the disease. The well-recognized cases of primary cutaneous actinomycosis are produced by contact-infection from germ-laden objects. Actinomycotic pus is thought to be a possible medium of infection. Hence the surgeon should carefully destroy the infected dressings and guard any small and otherwise insignificant wounds upon the skin of the patient or upon his own hands.

Although the infection atrium in the faciocervical form of actinomycosis is, as described, a carious tooth, a crypt of the tonsils, a fold of mucous membrane, a wound or an ulcer, direct evidence of the mode of entry usually disappears early in the course of the disease.

Indeed, a wound or ulcer may heal entirely, leaving no visible trace, while actinomycosis is going on in neighboring structures. Once the disease is recognized in the cheek or in the connective tissue or skin of the neck, a tell-tale band of scar-tissue may guide the diagnostician to the infection atrium.

As actinomycosis is essentially a chronic process, scar-formation may obliterate the disease at some points, while at others it is active. Hence the patient may come to the surgeon for an insignificant induration upon the jaw, in the skin of the cheek, or in the superficial cervical fascia. The disease is usually painless, and mechanical signs are often the only manifest phenomena. If the lower jaw is attacked, ankylosis, either spasmodic or fibrous, is usually present in varying degrees. The disease in the skin, at first showing induration only, is soon characterized by softening at the center of the nodular mass and reddening of the skin. Illich compares the appearance to that of an inflamed sebaceous cyst. If the fluctuating center is incised, the characteristic granules are discovered in the detritus or pus. When these infiltrations occur over the jaw, they are usually adherent to the bone. As secondary mixed infection almost always takes place when the foci are opened, the constitutional disturbances take on the phenomena seen in pyogenic infection. The disease infiltrates the skin progressively but irregularly, throwing it into knobs and masses which are separated from one another by depressions. Usually a number of sinuses discharge upon the skin at different points.

The disease thus localized may terminate in recovery, especially if surgical aid is extended; but it may end fatally by extension to the meninges of the brain or to the chest-cavity, by metastases to distant viscera, or by secondary septic processes.

Jurinka reports a case of lingual actinomycosis, Koch an instance of a parotid localization, and Marchand two examples of esophageal actinomycosis. In one of these cases a small perforation of the esophagus near the cardia was observed, and in the neighborhood was an extensive sacculated abscess with actinomycotic pus.

The disease, when it involves the face and neck, is of slow evolution. Side by side the processes of destruction and proliferation go on, with the result that labyrinthine sinuses, opening at numerous points on the skin, burrow in the superficial fascia, about the muscles of the neck, and often along the course of the great vessels or along the maxillary bones.

The **pulmonary localization** of the disease, thought to be instituted by the inhalation of the infectious agent, is regarded as the gravest form of actinomycosis.

Illich, after an exhaustive study of the literature in 1892, cited only two cases of recovery in pulmonary actinomycosis. The high mortality he thinks due to the inaccessibility of the disease, but more especially to the fact that it spreads so extensively, not only through the lung-tissue but through the pleura, the peripleural tissue, and into the neighboring bones. Sinuses opening in various directions are likely to form, and surgical procedures, although properly indicated, are likely to be of no avail, from the fact that all foci of disease cannot be reached and extirpated. The disease in this situation simulates tuberculosis pulmonum very closely in a clinical way as well as in its gross anatomical progress (Illich). Except where the disease—frequently located in the lower lobe of the lung—destroys life by some pathological catastrophe, as by rupture through the diaphragm, it is likely to kill by exhaustion and septic intoxication due to mixed infection.

Abdominal actinomycosis is thought to take origin in ingested bacteria, to the localization of which no part of the gastro-intestinal

tube is immune; but those parts of the intestine which are peristaltically least active are most likely to be affected. This is especially true of the cecum, actinomycotic inflammation of which simulates recurring attacks of appendicitis. Abdominal actinomycosis, localized in structures of widely varying anatomical peculiarities, gives rise to a wide range of symptoms. "There are," says Illich, "cases which point to disease of the iliopsoas muscle, others where abdominal pains, sometimes vague, sometimes localized, or cramps, colic-like attacks, and vomiting occur. All sorts of disturbances of defecation have been observed, even to tenesmus, with discharge of mucus." In general, these varying symptoms are associated with the occurrence of an abdominal induration. An infiltration may extend outward from within until it involves the skin, and a diagnosis is made upon the discovery of the actinomycetes in the discharge. The pathogenic organism may be discharged by the rectum or the bladder. The greatest difficulty in treatment is encountered when the disease involves branches of the portal vein, since actinomycotic liver-abscesses are then likely to make their appearance and to dominate the symptomatology of the disease. Nevertheless, a number of cured cases of the abdominal form of actinomycosis are now on record. These cases are sometimes instances of spontaneous recovery; sometimes are due to a combination of medical and surgical methods of treatment.

Actinomycotic disease of the female generative organs has been reported, but is usually secondary to disease originating in other parts of the abdomen. Rarer localizations of the disease are the middle ear, the larynx, the mammary glands, and the lacrimal ducts.

Actinomycosis is capable of dissemination through the system in the guise of pyemia. Secondary actinomycotic foci may then be found in the most widely separated viscera.

In the **diagnosis** of the disease, it is essential to bear in mind the clinical characteristics already portrayed; but these alone are not sufficient to distinguish it from various forms of the other infectious granulomatous diseases—*e. g.*, tuberculosis, syphilis, etc. The cutaneous form of the disease, by its irregularly nodular indurations, is suggestively characterized; but even here we seek other signs. The crucial test of the disease is fortunately applicable in the great majority of cases of the disease—viz., the discovery of the micro-organism, the peculiar yellow bodies floating in the pus. These masses should be examined carefully with the microscope, since granules of tubercular detritus sometimes simulate them in gross appearance. The nodule is placed on a glass slide, a cover-slip is laid over it, and a little pressure applied to the cover-slip crushes the body. The radiating clubbed filaments may then be recognized.

The localized forms of tuberculosis, especially in the skin, are best distinguished from actinomycosis by the bacterioscopic findings. But the fact that in tuberculosis the regional lymphatic glands are often affected, while the actinomyces does not tend to disseminate itself in this way, should aid the diagnostician.

Carcinoma of the tongue is situated usually near the base, while actinomycosis is localized near the tip. Besides this, the lancinating pain, the tenderness, the tendency to ulceration, and especially the

glandular infiltration, aid in the distinction. Syphilis is to be excluded by the collateral evidences of the disease and by therapeutic adjuvants. Actinomycosis of the lungs simulates tuberculosis so closely that a distinction without microscopical evidence is impossible. Usually the disease attacks the lower lobes of the organs, and sinuses leading to the skin are formed. The granules discovered in the pus are then of decisive value.

It is equally essential in the diagnosis of the abdominal form to find the actinomyces in the pus before reaching a diagnosis as to the cause of the easily discovered induration (Korányi).

Treatment.—Actinomycosis in cattle is to a considerable degree amenable to internal medication by potassium iodid, suggested in 1885 by Thomassen of Utrecht for that disease when localized in the tongue. Eighty cases treated by him were all cured. Nörgaard, of our Bureau of Animal Industry, first applied the remedy in the treatment of actinomycosis of the jaw, and with success. Of 185 affected animals purchased by the Bureau of Animal Industry, 131 were cured by this drug. "In most of these cases," says Dr. Salmon, "after treatment was finished, there was only a bunch of fibrous tissue to show where the tumor had been." To these animals only 1½ to 2½ drams (6 to 10 gm.) per day were administered. Iodism appeared in the course of a week or ten days. The treatment was then suspended for a few days, to be again renewed for a time. Cures have often been effected in two weeks, but usually treatment is required for twice that period.

In man, a variety of remedies were vaunted before potassium iodid gained its present therapeutic status. Corrosive-sublimate injections (Albert), tuberculin (Billroth), carbolic acid and glycerin with methyl violet (Raffa), and silver-nitrate sticks introduced into the sinuses (Köttnitz) have all been used, according to Jurinka, with more or less success. A long list of cases treated, and for the most part cured, by potassium iodid is cited by the last-named author. The dose as used by Buzzi and Galli-Valerio was 30 gr. (2 gm.) daily, the treatment being continued for two months. Netter began with a dose of 90 gr. (6 gm.) daily, then diminished to 15 gr. (1 gm.), which was continued until in one month a cure was effected.

The experiments of Jurinka upon the ray-fungus *in vitro* do not indicate a direct bactericidal action on the part of the drug; but his finding of iodin compounds in the pus of patients taking the drug proves that it has abundant opportunity to reach the seat of disease. It is believed that it acts by increasing local tissue-reaction. Wölfler, in whose clinic Jurinka conducted his studies, appends a note to the article of his pupil, in which he further commends the use of the iodid and adds another case to the list of cures.

We must admit that this treatment is to be tried persistently in all the inaccessible forms of the disease, and tentatively in its more superficial manifestations; but adverse reports of cases in which the drug was tried without success are not wanting. The failures are in many cases doubtless due to the extent of the disease, to the virulence of the infection, to a secondary mixed infection, or to an inherent lack of resistance on the part of the individual attacked. It is possible that

there are several varieties of the cladothrix grouped under the title actinomyces, which have different degrees of invasive activity and varying powers of resistance to the action of potassium iodid and the granulation-tissue proliferation which it excites. These questions are for the future to decide. The writer observed one case of the faciocervical type in which the drug had no visible effect.

G., farmer, aet. cir. fifty-five years, toper, noticed a swelling under the left inferior maxillary bone in the region of the submaxillary gland. A dentist extracted the second left lower molar tooth, which was carious. No relief followed this sacrifice. The swelling continued to increase very slowly for four or five months, when the patient was referred to me by Dr. Byron Robinson. At that time the swelling was about the size of a hen's egg and was adherent to the inferior maxilla, over which it was immovable. The swelling was hard, diffuse, and indistinctly outlined. The skin over the mass was adherent, especially over the most prominent part of the tumor, where two sinuses opened. The skin about these openings was bluish in color and thin, and from the sinuses was discharged a thin serum-like pus which contained, here and there, the characteristic granules of actinomycetes. When the patient was anesthetized and the skin opened the sinuses were seen to run in various directions, honeycombing the superficial fascia and at times perforating it. The periosteum of the inferior maxilla was attacked, and at points the bone was denuded. No lymphatic glands had been attacked. The operation was therefore limited to a thorough curetting and careful excision of all infected tags of tissue with the scissors. Iodoform-gauze packing was kept up carefully until the wound was covered with granulations, when the patient went to his home at a distance. After an interval of about three months, the patient returned, and stated that the disease was spreading. It was found to have extended downward along the superficial fascia for about two inches, with numerous pockets and blind sinuses lined with flabby granulations secreting a thin pus, which contained, as before, the actinomyces-kernels. The parts were again thoroughly curetted, and diseased tissues clipped out with scissors. The patient went home, and in about five months again returned with a recurrence. This time it was decided to operate radically. With this end in view, the tissues were thoroughly opened and all invaded parts exposed. A dissection was made as carefully as possible, almost as extensively as for malignant disease, the incision extending almost to the clavicle below. The inferior maxilla, which had been curetted at the second operation, was at this time found so deeply invaded by the actinomycotic caries that it was deemed best to partially resect it. The resected portion included all that part of the bone extending from the canine tooth to the articulation of the left side. Particular care was taken to dissect out the fascia as far as the disease could be detected. The patient bore the operation well, getting out of bed on the second day and walking about the hospital. His wound made excellent progress, healing through a considerable extent by first intention. A sinus, however, remained, and eventually began discharging actinomyces granules. At this time potassium iodid was given in increasing doses for several weeks until iodism was induced. No effect on the disease was visible at any time. The patient returned to his home and began a systematic course of drinking, and after four or five months died of a basal meningitis.

Besides the fact that potassium iodid was found of no avail, this case is interesting because of the great resistance of the infection to operative procedures.

We know that the disease of the faciocervical type is usually amenable to the simpler surgical procedures. The writer had proved this in the case of a young laundryman who had actinomycosis of the lower jaw near the angle of the right side. The origin of the disease in this case could not be traced. Simple curetting sufficed to effect a permanent cure.

Dr. L. L. MacArthur reported before the Chicago Gynecological Society a case of mammary actinomycosis in which potassium iodid was of no avail, and in which amputation had eventually to be resorted to.

The curious case is now under the observation of a medical friend of the writer, of a woman in whom a number of sinuses have been discharging actinomycotic pus for more than ten years. Potassium iodid causes an entire cessation of the discharge of actinomycotic

granules so long as its administration is continued; but when it is omitted for a few days the granules reappear. Thus the drug succeeds here in only checking the disease, but does not cure it.

Jurinka calls attention to the occasional recurrence of the disease after a superficial healing has been brought about by the iodid. This recrudescence may necessitate a return to the drug. It should be mentioned that Wölfler frequently uses applications wet with potassium-iodid solution as a local adjuvant to the internal treatment with the same agent.

We should begin the treatment of actinomycosis, then, in all accessible forms of the disease by the simpler surgical procedures, regarding the process not as a malignant one, but as a malady which under favorable conditions can be overcome by the tissues. Potassium iodid is to be employed as an adjuvant in these cases, and as an independently curative agent in the inaccessible forms of the disease. In those forms of the disease in which the process has gone too far for successful extirpation, the surgeon should open all accessible collections of actinomycotic pus, split such fistulæ as can be reached, scraping away the detritus, and, while continuing daily irrigations with suitable antiseptics, administer tonics and potassium iodid.

MADURA-FOOT.

Madura-foot is a disease of the foot observed most frequently, though not exclusively, in tropical and subtropical countries. Recognized as a distinct disease but a few years ago, and occurring but rarely under the observation of competent pathologists, madura-foot is as yet an imperfectly studied disease. That it is caused by bacteria and, in all probability, by the *Streptothrix maduræ* (Vincent), is scarcely to be doubted. This micro-organism, thought by many to be a form of actinomyces, is doubtless nearly related to that cladothrix, but, according to the most recent researches, does not seem to be identical with it. We again refer the reader for details to the chapter on Bacteriology.

FIG. 48.—Madura-foot or mycetoma (melanoid variety). Portion of amputated part, showing general appearances of the lesions on a section extending backward between two toes. The black granules are seen embedded in atypical granulation-tissue (Beach and Wright).

The **morbid anatomy** of the disease is clearly elucidated by Paltauf and by Vincent. In the soft parts of a specimen examined by Paltauf were numerous small abscesses containing pus in which were scattered quantities of granules of pin's-head size and smaller. By such abscesses the soft parts appeared separated from the carious and porotic bone.

Paltauf called attention to the fact that in actinomycosis proliferation and osteophyte-formation are observed.

In Vincent's case, quantities of ovoid and globular whitish-yellow granules were discharged. These granules were composed of mycelia closely interwoven. These masses of mycelia were found in the tissues at the centers of vascularized tubercle-like nodules, which were found grouped together very frequently. The skin over such masses was atrophic. About the nodules of mycelia, a connective-tissue reaction had taken place together with leukocytic infiltration and fibrinous infiltration. No caseation changes were seen.

FIG. 49.—Same case as Fig. 48, showing outgrowth of fungus filaments from one of the black granules. Low magnifying power (Beach and Wright).

Dr. James H. Wright describes the parts removed by Dr. H. H. A. Beach from the foot of an Italian woman suffering from this disease, as follows: "The dissection of the amputated part showed the following conditions: In the soft tissues of the plantar surface of the foot, near the tarso-metatarsal articulations and immediately beneath the skin, was a pigeon's-egg-sized ovoid tumor-mass, sharply defined from the surrounding tissue by a faintly indicated

FIG. 50.—Same case as Fig. 48. Two bouillon cultures of the fungus, showing the powder-puff appearance of the growth. In one the black granule is seen in the center of the mass of filaments (Beach and Wright).

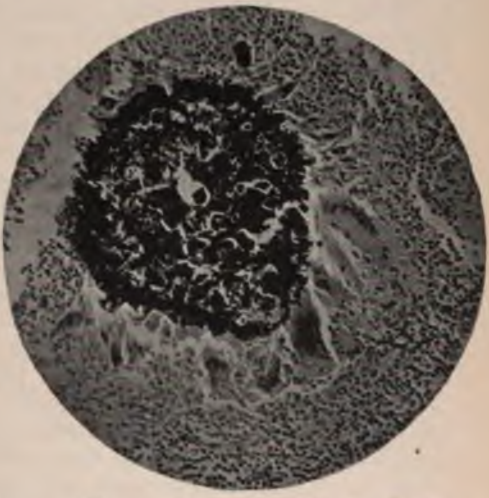


FIG. 51.—Same case as Fig. 48. Section showing a granule with surrounding giant cells (Beach and Wright).

connective-tissue capsule. This mass on section consisted of a soft, in places gelatinous, myxomatous-looking tissue, traversed by a reticulum,

which divided it into ill-defined small areas, and in these areas small, black, irregular granules like gunpowder grains were present. These grains occurred singly and in groups. The tumor-mass in one or two places also presented opaque yellow areas. Two other similar nodules of small size were also found. One was situated in the soft tissues of the dorsum of the foot, near the base of the second and third toes, the other in the soft tissues of the first phalanx of the second toe. The larger of these nodules was of about the size of a pea. The bones were not involved."

Symptoms.—The disease begins either upon the plantar or dorsal surface of the foot, and gives rise to a painless diffuse swelling of its soft coverings. Hard nodules appear, but later soften, break down, and discharge upon the skin a pus containing granules of the mycelia already mentioned. In certain cases attended with pain these swellings remain hard.

Two forms of the disease are clinically distinguished—that in which the granules are black, and that in which they are white. The disease is of slow evolution. The leg involved becomes atrophied, weak, and useless. Death occurs as a result of exhaustion, or of complications which are only indirectly the result of the primary disease.

The **treatment** thus far employed successfully is amputation.

THE BITES OF SERPENTS.

The wounds inflicted by the fangs of non-poisonous serpents give rise to no more disturbance, local or systemic, than is observed from ordinary wounds inflicted by unclean instruments. The bites of poisonous serpents are more or less dangerous owing to the injection of toxic substances at the moment the injury is inflicted.

Varieties of Serpents.—Of the 1500 or 1800 species of snakes (ophidia), there are five kinds, if we divide them according to their mode of life and habitat: (1) burrowing snakes, living chiefly underground, non-poisonous; (2) ground snakes, chiefly non-poisonous; (3) tree-snakes, some of which are poisonous, while others are non-poisonous; (4) fresh-water snakes, almost all non-poisonous; (5) sea-snakes, which do not leave the water and are poisonous. Serpents exist in greater variety and numbers as we approach the tropics.

Of the venomous serpents, the various members of the Naja genus—the cobras—are much dreaded in India and Africa. The mortality from snake-bites in India is very high. In the province of Burdwan, with a population of six millions, more than one thousand deaths occurred annually for nine years. Of course, there are other venomous serpents in India, which are partly responsible for this death-rate. Tropical America has a genus of especially venomous serpents in the pit-vipers. Smaller members of the same genus are found in the temperate zone of North America. Of these there are two species, the copper-head and crater-moccasin. The rattle-snakes, members of the pit-viper family, are found exclusively in America. The large family of vipers, including the asps, are the chief venomous serpents of Europe.

All venomous serpents possess especially differentiated poison-fangs, which are situated at the roof of the mouth. At the base of the fangs

are venom-elaborating glands with sacs for containing a supply of the poison. When the animal strikes, the fangs take a position perpendicular to the edge of the jaw, the tooth penetrates the tissues of the victim, and at that moment the venom is injected into the subcutaneous tissue through a small canal in the poison-fang.

Symptoms.—The action of the poison is thus sudden and overpowering in proportion to the quantity of the poison and its deadly quality. When a vein is penetrated, the effect is especially sudden and violent. Serpents' venom brings about a painful swelling at the site of injury, coagulation of blood, and consequent thrombosis of blood-vessels. The general symptoms are collapse, more or less complete, convulsive contractions, and vomiting. Gangrene or anesthesia is occasionally noted. Death usually occurs in the first forty-eight hours. If the patient survives this period, he is likely to recover.

The local **treatment** of poisoning by snake-bites, when the injury occurs upon the extremities, consists in the immediate constriction of the limb and the free incision of the skin about the wound to allow the escaping blood and lymph to wash out the venom. This may be aided by sucking the wound, a procedure which is not dangerous unless wounds of the mouth exist. Injections of chemical antidotes may be employed if they are at hand; but it is useless to apply them if evidences of systemic poisoning indicate that the dissemination has already begun. Of the chemicals employed, potassium permanganate in 5 per cent. solution in water is the best as yet known. Two to three drams of the solution should be used in the tissues about the wound. Other substances are in use for injections—especially sodium hypochlorite, chromic acid, and chlorin water.

The systemic treatment by the use of *antivenomous serum* has been proposed by Calmette, whose success in the production of immunity by injecting successively larger doses of poison into susceptible animals is well-known. He has successfully treated poisoned animals which had not been previously immunized, by the injection of the serum of protected animals. Fraser has dried the serum of immunized animals, and finds its qualities unimpaired by drying and storing. Practical applications of this method in actual cases have not as yet been made often enough to give definite data as to its value.

H. P. Keatinge[1] reports a case of snake-bite treated by antivenene serum. A child was bitten on the forearm by an Egyptian cobra; she almost instantly became unconscious. The village barber made several incisions on the arm and forearm. When brought to the hospital she was cold and collapsed, pulseless, with rambling delirium. It was found that the forearm had been coated with Nile mud, which is a favorite native remedy; three inches below the bend of the elbow two distinct holes were seen passing through the skin and corresponding to the fangs of the serpent. It was noted that the pupillary reflexes were absent; the pupils were moderately dilated. The child became comatose. 320♏ (20 c.c.) of antivenene serum were injected under the abdominal skin. In four hours her condition was distinctly improved. 160♏ (10 c.c.) of the antivenene serum were again injected. She then

[1] *Brit. Med. Jour.*, Jan. 2, 1897.

slept during the night, and the next morning was notably better. The serum used was Calmette's antivenene serum.

Strychnin, ammonia, and alcohol are used to overcome the depression caused by the poison. The practice of inducing intoxication by the use of large quantities of whiskey is to be condemned.

INSECT-BITES.

The bites and stings of many insects are painful and annoying only to a degree corresponding to the traumatism inflicted. In the case of mosquitoes, bees, hornets, tarantulas, ordinary spiders, etc., poisons are usually introduced into the wounds inflicted, and cause a disproportionate wound-reaction.

Symptoms.—Within a few minutes, in the case of persons susceptible to the action of these poisons, swelling takes place about the point of injury, and hours may pass before the edema disappears. Itching and pain accompany the redness and swelling. If loose tissues are attacked—as about the eyelids—the swelling may be very distressing in its consequences.

It is only when the poison is thrown directly into the circulation that serious symptoms follow a single bite or sting. Some individuals are especially susceptible to this form of poisoning, and are rendered ill by it; while others are not troubled even by numerous bites. Managers of apiaries are said to acquire a well-marked immunity to the poison of bees, so that the wounds cause them annoyance solely on account of the traumatism produced.

The infliction of a large number of bites or stings may have serious consequences owing to the quantity of poison introduced; indeed, deaths are known to have occurred in not a few instances from this cause.

The nature of the poisons which are introduced has been but little studied. It is supposed, however, that, like the poisons of the venomous serpents, they are of the nature of leukomains.

The **treatment** of insect-bites and stings is by the application of cooling lotions and the local use of various drugs supposed to have a more direct action on the poison and on its pathological consequences. Of these, ammonia and some of its compounds are very frequently used. Ottinger recommends ichthyol, either pure or mixed with an equal quantity of lanolin. Camphor, camphor-chloral, and menthol are recommended.

CHAPTER IX.

GANGRENE.

Classification.—The Greek word *γάγγραινα*, from *γράειν*, to gnaw, meant an eating sore, such as phagedena and hospital gangrene, but is now a general term for the partial death of the tissues, especially of the extremities. *Σφάκελος*, from *σφάζειν*, signified the process ending in the death of the tissue, hence "sphacelation" is equivalent to "mortification." "Sloughing" is the process of separation and casting off the dead tissue from the living, as a serpent sheds its epidermis.

The immediate cause of the death of a part is the failure, whether partial or complete, of the circulation through the part. The complete arrest of the circulation through the skin, bone, or connective tissue for twelve hours certainly causes death, and a much shorter period is sufficient for softer parts.

It is impossible to distinguish sharply the different forms of gangrene, since there is so much interaction of the various causes. The division into *dry* and *moist* gangrene is largely accidental. Traumatic gangrene cannot be separated from the idiopathic form due to disease in those cases where the traumatism consists in inoculating septic organisms, or where a small cut on the toe is the exciting cause of gangrene owing to the diseased condition of the patient's vessels.

The term *Raynaud's disease* is often used so as to include various kinds of gangrene. Raynaud emphasized symmetry and paroxysms in cases where arterial obstruction is absent. But the term Raynaud's gangrene is sometimes applied to any case of symmetrical gangrene, although the symmetry may result from heart failure, thrombosis, or symmetrical arterial disease. Paroxysmal symptoms frequently usher in gangrene due to arterial disease. Even amongst the cases to which the name of Raynaud is more properly attached, there is one set in which anemia and cardiac weakness are also present, and another class characterized by thickened tortuous arteries with high pulse tension in comparatively young patients. Such cases may be asymmetrical, confined to one limb, and show no paroxysms.

The term "*spontaneous*" as applied to cases of gangrene becomes more and more unsuitable as the pathology of gangrene is better known.

The predominating factor in gangrene is the partial or complete failure of the blood-flow, and therefore in this article the subject of gangrene is considered according to the most prominent and immediate cause of the circulatory failure—viz., (1) the impairment of the general circulation, (2) obstruction of the main arteries and veins, (3) obstruction of the smaller arteries, (4) spasm of the arterioles, (5) obstruction of the capillaries and venules.

There are two practical considerations which control the description of gangrene here given; first, the prevention of the various forms of gangrene, and second, the opportune removal of the dead part, so as to bring about healing and save life.

Mortification.—When a part dies as a whole and at once, the dead part undergoes the same changes as does the body after death.

The skin becomes absolutely cold, white, and sometimes marbled by the stagnant blood in the superficial veins. Rigor mortis quickly sets in, and passes off with the onset of putrefaction. On cutting into the part, the only blood which escapes comes from the veins; the proximal ends of the cut arteries are quite empty, and muscle-serum oozes from the rigid muscles. Swarms of bacteria soon appear, the subsequent putrefactive changes being dependent upon the amount of heat and moisture present. When the limb is affected above the wrist or ankle, and venous stagnation has preceded the absolute arrest of the circulation, the limb undergoes "moist gangrene"—*i. e.*, those putrefactive changes which take place in a moist and warm atmosphere. The hemoglobin diffuses out and stains the deeper part of the skin a dusky brown which becomes more and more green. A distinctly foul odor is perceived. The epidermis is easily detached, showing a green dermis beneath. Then patches of green skin separate and come away with the least touch, exposing the muscles which are seen to be falling apart and liquefying. On the contrary, when the arterial circulation has been arrested without impeding the venous return, the part is comparatively free from moisture, and in a dry atmosphere undergoes "dry gangrene." This is especially seen in the hands, feet, tips of the ears and nose. The tissues shrivel up and become hard, like a well-preserved mummy, in which the structure of all the harder tissues remains unaltered. The cold, dead-white or marbled limb begins to shrink; the skin becomes hard and horn-like, and rings when struck. The color changes to a dark olive-brown, then becomes blackish. There is little more than a musty odor. When the muscles are cut into, some may be found still containing moisture and of a uniform red; later on, these likewise shrivel up, leaving horny, brownish-black material. The action of putrefactive organisms is prevented by the lack of moisture.

Sloughing is the separation of the dead part from the living. In this condition a line of demarcation gradually appears at the margin of the living skin where it borders on the dead. At first, this line is ill defined—in dry gangrene on account of the feeble circulation in the living, and the slight amount of putrefaction in the dead, tissue; in moist gangrene because the line is irregular, not forming a circle round the limb, but varying according to whether cutaneous arteries are obstructed or patent.

In the dead part there is an absence of sensation; in the living there is hyperesthesia, increasing to pain in the region of the line of separation. A dead part shows no capillary circulation and is absolutely cold; in the living there is at least some circulation, so that the skin becomes paler on pressure with the finger and recovers some color on releasing the pressure. When a part is swollen and pits on pressure, if the pitting remains after relaxing the pressure, the circulation is insufficient and gangrene is threatened; if the pitting disappears on taking off the finger-pressure, a blood-supply enough to maintain the life of the tissues is indicated. The dead part remains cold; the living increases in warmth, especially in the region of the line of demarcation, until a zone of inflammatory redness becomes apparent. When gangrene supervenes on acute inflammation, the redness of the dying and

dead tissue grows more dusky and does not alter on pressure, the color becomes bluish, then greenish, and a fetid odor is apparent. The still living tissue remains brightly red, the redness diminishing on pressure, but returning immediately the pressure is taken off. The bright inflammatory zone in the living part fades away into the healthy skin above. At the lower margin of the living tissue, a line of pustules forms beneath a layer of whitish epidermis. On raising the epidermis and washing away the pus, a gutter-like ulcer is seen, which extends through the skin. The ulcer encircles the limb and becomes gradually deeper, forming "the line of demarcation."

In dry gangrene the muscles are usually better supplied with blood than the skin, and the bone better than either, so that the typical result in dry gangrene after spontaneous separation is a conical stump with the bone projecting beyond the soft parts.

In moist gangrene muscles may slough beneath intact skin, and the shaft of a bone may undergo necrosis up to the joint above. Beneath the skin, vascularity is the indicator of the living tissue. The living bleeds when cut into; the dead does not, owing to septic thrombosis. The living muscle and bone increase in vascularity owing to inflammation and ulceration excited by contact with the dead. Dead muscle breaks down into thin, foul, greenish pus, the connective-tissue sheaths, fascia, and tendon form yellowish or grayish-white tough sloughs, the bone becomes white or greenish-white and rings when struck.

The Effect of the Dying and the Dead Tissues on the Body generally.—Putrefaction is a process of oxidation ending in the formation of carbonic acid, water, and free nitrogen. But abundance of oxygen is required to carry out this process rapidly. Wherever the oxygen from the atmosphere cannot freely reach, the oxidation is relatively slower and the number and persistence of intermediary products relatively greater. These act locally on the living tissues and set up suppuration in them, from which septic products enter the circulation. Proteids form poisons containing nitrogen, carbon, and hydrogen, allied to the poisonous alkaloids found in plants and to the precursors of urea and uric acid. The sulphur forms sulphuretted hydrogen. Non-nitrogenous carbohydrates and fats produce irritating acids, lactic acid, and other fatty acids, also poisonous gases, such as marsh gas. In the presence of abundance of oxygen, such substances are rendered harmless by oxidation. Putrefaction is partly or wholly stopped by desiccation, the albumins drying up into a horny substance.

The body is directly affected by the actual loss of the dead part when a limb is suddenly crushed or the main artery obstructed by an embolus; shock is then produced just as if the limb had been amputated.

Absorption of the poisonous products from the dead part ceases when the circulation is arrested, and so this is only of importance in partial and spreading gangrene. In dry gangrene there is very little absorption, even although the circulation has not quite stopped, because the return circulation is so very small. The drier, therefore, the dead tissues and the more freely they are exposed to the atmosphere, the less is the irritation of the living tissues. The more moist the gangrene

and the less the oxygen penetrates to the decomposing tissues, the more dangerous is the poisonous influence upon the living. The local reaction of the living tissues is then marked by profuse ulceration and suppuration, and septic absorption is indicated by the general condition of the patient.

Partial and spreading gangrene causes much more absorption of septic matter relative to the extent of the gangrene. In partial gangrene the return circulation brings back substances from the dying tissue, and when there are scattered patches of gangrene the area of contact with the living tissues is much greater. In spreading gangrene previously healthy tissue is being continuously invaded, and fresh absorption is originated at each stage. Moreover, the removal of the dead part is apt to be delayed or to be incomplete, owing to the uncertainty as to the line of demarcation.

Ischemic Degeneration.—Whenever the blood-supply becomes insufficient, the cells of the skin and muscle, as well as the blood-corpuscles, exhibit signs of degeneration. The change commences in the nucleus; the chromatin filaments break up into lumps, granules, or refracting bodies, and no longer stain with nuclear dyes. The nucleus is dissolved in the protoplasm, which then liquefies, so that the whole cell is broken down and disappears. The striæ fade from muscle-fibers, leaving a homogeneous semi-fluid substance, which ruptures the hyalin sheath. The hemoglobin of the red corpuscles is first reduced, then rendered iron-free, and so comes to resemble the bile-pigments.

An insufficient blood-supply may cause a limb to become weak or completely paralyzed and atrophied. If the failure of the blood-supply stops short of causing gangrene, ischemic rigidity and paralysis are followed by an interstitial myositis and permanent contracture. A limb, after becoming insensitive and cold, may commence to shed its epidermis, and yet stop short of gangrene. If the heart's force is increased or the collateral circulation is established, warmth and sensation return, and there is simply desquamation.

I. GANGRENE FROM IMPAIRMENT OF THE GENERAL CIRCULATION.

Fatty degeneration with exhaustion of the heart-muscle is a great predisposing cause of gangrene, yet, as long as the circulation is equally distributed, no gangrene need actually start. When, however, an artery is blocked by embolism or thrombosis, the collateral circulation is insufficient to maintain the life of the tissues. Embolism is the result of endocarditis; if it is acute, the emboli are septic, and the danger of moist gangrene the more likely. Chronic endocarditis gives rise to embolism either by the formation of fibrin or by the detachment of a vegetation from a valve. A slow and feeble circulation consequent on cardiac weakness tends to produce thrombi in the heart, from which emboli may be detached, and also thrombosis in the arteries of the limbs, in which the circulation is especially feeble. A patent septum of the heart, producing cyanosis, predisposes to gangrene, owing to the imperfect aëration of the blood. The morbus cæruleus is distinguished by being general, including the lips, and the color is blue as compared with the local dusky red, tending to green, of gangrene.

Cyanosis from bronchitis, emphysema, etc., has the same influence. A diminution in blood-pressure also predisposes to gangrene, so that exhaustion, want of food, and loss of blood render the wounded lying on the ground after a battle liable to gangrene, although the temperature does not fall below freezing point. Acute diarrhea and cholera tend to cause gangrene by weakening the circulation and producing thrombosis. The acute specific fevers and other exhausting diseases act in a similar manner.

In children multiple gangrenous patches may appear on the skin of the limbs and abdomen a few hours or days before death. Nothing is found post mortem except some soft thrombi in the main vessels of the limb affected. Sometimes such cases have been attributed to abnormalities of the blood-vessels (Solly[1]), but the apparent small size of the main arteries may well be secondary to the previous disease.

The symmetry often met with is vascular in origin, and is therefore distinct from the symmetry noted in Raynaud's disease, which is due to the distribution of the nerves.

Treatment.—Gangrene arising from a failure of the general circulation can hardly be foreseen, and in most cases the patient is too ill to complain of any premonitory symptoms. Careful watching and examination of the patient lead to the discovery that the limbs are becoming cold and losing sensation, or that dusky red, indurated patches are appearing on the skin. The occurrence of gangrene is warded off by improving the force of the heart, replacing lost fluid by saline infusions or rectal enemata, wrapping up cold limbs, and avoiding pressure and all causes of irritation. Surgical measures are necessarily dependent upon the condition of the patient, which is often beyond hope. If amputation is done, it must be at the level at which the main artery can still be felt patent, not below. Thrombosed and gangrenous patches of skin should be at once incised and iodoform gauze slipped beneath. This prevents further absorption from the slough, which is later on removed.

II. GANGRENE DUE TO THE OBSTRUCTION OF A MAIN ARTERY OR VEIN.

If a main artery is blocked, and the collateral circulation is not quickly established, gangrene must ensue. The anatomical conditions may be favorable for a collateral circulation, or they may be the reverse. Anastomosis is so complete in the case of the branches of the external carotid that the cut distal ends pulsate. On the other hand, there is no anastomosis between the branches of the pulmonary artery or of the superior mesenteric, and hence gangrene inevitably follows on obstruction of these vessels. The testis sloughs when both spermatic and deferential arteries are cut off. There is a sufficient anastomosis in the limbs to maintain life after the obstruction of the main artery, provided always that the smaller vessels are unobstructed. Anatomically the most unfavorable anastomoses are those rendered necessary when the common femoral and the axillary artery are

[1] *Med.-Chir. Trans.*, 1839, p. 253; 1840, p. 236.

blocked. When the common femoral is obstructed, the blood, in order to reach the foot, has to pass through a double set of capillaries—from those of the branches of the external and internal iliacs into the branches of the profunda femoris, and thence into the branches of the superficial femoral and popliteal—before it can reach the leg. The greater the anatomical difficulties in the way of developing the collateral circulation, the greater is the need of a good general circulation; and, conversely, there is greater danger of gangrene when the circulation is weak.

The chief obstacle to the development of a collateral circulation is the simultaneous obstruction of the smaller arteries and arterioles. This may take place from many small emboli, from thrombosis, or from a gradual narrowing of the lumen owing to disease, and also from outside pressure. The collateral circulation takes some little time to establish itself; hence a sudden and complete obstruction to a main artery favors the immediate onset of gangrene, whilst the slow development of an obstruction gives the collateral vessels time to dilate.

Obstruction to the return of venous blood predisposes to gangrene whenever there is at the same time septic thrombosis. The common femoral and the subclavian vein return most of the venous blood, but they may become obstructed without causing more than venous congestion, unless there be, in addition, septic inflammation, in which case moist gangrene will quickly set in.

A wound of a large artery is liable to be followed by gangrene, owing to the general circulation being weakened by loss of blood. Both wounds and ligation in continuity were formerly liable to be followed by gangrene, owing to the septic inflammation and thrombosis which spread immediately from the wound and obstructed the collateral circulation, or later, after loss of blood by secondary hemorrhage. As an aneurysm develops on an artery, it presents a gradually increasing obstruction to the blood-flow; but should the aneurysm become suddenly diffuse, the collateral circulation already developed will be thereby obstructed, and so gangrene will be likely to follow a ligation in continuity, although the operation be completely aseptic.

Main arteries become obstructed by emboli detached from the heart, or by thrombosis due to a feeble circulation or to disease of the arterial wall. The disease of the arterial wall is occasionally acute arteritis resembling acute endocarditis; but it is much more commonly atheroma, or arteritis obliterans. The main arteries are further obstructed by external compression, tumors, foreign bodies, bullets, and unreduced fractures and dislocations, and if at the same time the collateral circulation be partly hindered, gangrene is the more likely to follow.

The circulation through the main artery, as well as the collateral circulation, is obstructed *in utero* by bands formed in the fetal membranes. Both lower extremities have spontaneously separated at the hip-joint (Duer[1]). In Maddin's[2] case amputation at the junction of the upper and middle thirds of the thigh was successfully carried out on the third day after birth.

[1] *Brit. Med. Jour.*, 1897, vol. ii., p. 1179.
[2] *New York Med. Rec.*, 1889, vol. i., p. 461.

PLATE 7.

Gangrene from arterial thrombosis

The elastic band has been applied so as to cut off the circulation in a limb for as long as four hours. Such application is apt to be followed by dilatation of the arterioles from loss of tone and by venous congestion, in consequence of which sloughing of the skin has taken place (Wilkes[1]). When the elastic tourniquet is applied below the elbow or knee, the wall of the artery may be bruised and thrombosis set up. Gangrene of a finger or of a thumb has been brought about by an elastic band being placed round the base to stop bleeding.

Thrombosis in a large vein is caused by compression and also by an increased coagulability of the blood. This latter is due to septic causes, and follows especially puerperal and typhoid fevers; it is probably connected with an excessive destruction of leukocytes. The thrombosis of a main vein from such a cause is frequently accompanied or followed by thrombosis of the corresponding artery.

Obstruction of the Abdominal Aorta and its Branches.—The abdominal aorta may be obstructed congenitally, also by an aneurysm which has been obliterated by clot, by thrombosis from atheromatous disease or injury, and by embolism. Obstruction of the abdominal aorta may give rise to no obvious symptoms, unless there be in addition a simultaneous obstruction of the iliacs. When the thrombosis extends into the femorals, severe symptoms arise, owing to the interference with the collateral circulation through the epigastrics from the internal mammary and lumbar arteries. When the femoral is blocked by a clot, especially if the thrombosis extends into the popliteal, gangrene follows.

The **premonitory signs** of gangrene peculiar to obstruction of the aorta combined with those of its branches are symmetrical intermittent lameness and symmetrical paralysis, and paraplegia.

Intermittent lameness from obstruction of the abdominal aorta and iliacs has received the special attention of French writers. Its occurrence in the horse was noted by Boullay,[2] Humbert,[3] and others, and, later in man, by Charcot.[4] The horse starts out of the stable apparently sound, but, being pushed to a hard trot, comes suddenly to a standstill. The animal breaks into a sweat while the hind limbs are rigidly immobile, or falls to the ground in great pain with the hind limbs rigidly extended. The symptoms pass off after a short rest to reappear on forced muscular exertion.

Numerous dissections have shown that this intermittent lameness is caused by thrombosis of the hind end of the abdominal aorta and of the iliacs, due either to a rupture of the inner coats by strain, or to arteritis in connection with overwork. The rigidity is ischemic, a condition of temporary rigor mortis produced in the muscles by cutting off the circulation (Brown-Séquard[5]).

Painful intermittent lameness and paralysis were due in Charcot's case to a traumatic aneurysm caused by a bullet that had obliterated the common iliac artery. The symptoms appeared on walking and passed off on rest. Death occurred from bursting of the aneurysm into the intestines. In Terrillon's[6] case of a hard drinker aged twenty-seven, the pain came on in the leg and foot immediately on movement, so that he could go only a few steps, and then all further motion became impossible. He had no pain whilst at rest. These symptoms continued for two years. The limb became colder and gradually gangrene supervened and extended to the middle of the leg. In Jean's[7] case a woman aged thirty-eight had for some years become paraplegic on any extra exertion. After rest she was able to get about again,

[1] *Med. Times and Gazette*, 1880, vol. i., p. 540.

[2] *Archiv gén. de Méd.*, 1831, t. xxviii., p. 425.

[3] *Rec. de Méd. Vet.*, 1884, vol. ii., p. 440, and many other cases in later volumes of this periodical.

[4] *Gaz. méd. de Paris*, 1859, p. 282.

[5] Leçons sur les principales formes de Paralysie des membres inférieures, 1865, p. 68.

[6] *Revue de Chir.*, 1886, vol. vi., p. 813.

[7] *Bull. de la Soc. Anat. de Paris*, 3me., sér. x., 1875, p. 232.

but the legs began to drag afresh upon the least fatigue. Gradually the paraplegia became continuous, and she died of enteritis. The aorta and common iliacs were found completely blocked, the anastomosing vessels dilated, the femorals and popliteals normal. Sometimes the onset of the obstruction is obscure; in others it is well marked, some improvement taking place afterward as the collateral circulation increases. In Gull's[1] case a man of thirty-four felt a sudden pain in the loins, with desire to go to stool. He became completely paraplegic from the loin downward, including the sphincters. After a few days there was a return of sensation, and later on he was able to take a few steps, but was soon brought to a standstill by increasing numbness. He gradually recovered walking power, but the muscles were thin and languid, the feet cold and damp. No pulsation could be felt in the aorta or femorals. The superficial epigastrics were much dilated and the blood-stream in them downward. The lumbar and intercostals, likewise, were much dilated right up to the axilla.

A man of forty-two, described by Olliver,[2] suffered from syphilitic arteritis and thrombosis. Pain and coldness suddenly started in his foot while at dinner. The great toe became very cold and swollen, the limbs full. After he had walked for two or three minutes, he had to stop suddenly, and while resting he felt no pain. These symptoms abated in warm weather and were easily borne. The symptoms were most marked in the right limb, no pulsation could be felt, and the limb atrophied. On the left side they were less severe and some pulsation could be felt in the arteries.

The obstruction of the aorta and its branches may occur symmetrically with great suddenness as a complication of some exhausting illness. Latterly a number of cases have been recorded following upon influenza (Gould). Gangrene sets in, and the determining cause of the gangrene may be found in the obstruction, not only of the aorta and iliacs, but also of femorals and popliteals. When the obstruction is less extensive, the force of the heart may be sufficient to develop the collateral circulation. When there is thrombosis in the veins as well as in the arteries, the gangrene is moist; when only in the latter, the gangrene may be dry in the leg and foot.

Treatment.—When the premonitory symptoms above described are recognized, or when the limb is found cold, dead-white, and all sensation and pulsation are absent, the limb must be wrapped in cotton wool and raised in order to favor the venous circulation. Rest is required lest any further clot may be detached and pass into peripheral vessels. This treatment, along with an improvement in the general circulation, may give time for anastomosis. Gangrene having set in, it is necessary to decide whether the case is hopeless, or whether an attempt should be made to save life. If amputation seems advisable, it should be done without delay. If, as is usually the case, the gangrene is symmetrical, it is all the more important to attack the most advanced leg early, so as to allow an interval of a few days or a week to elapse before the second leg is removed (Gould[3]). On the other hand, the gangrene may be so far advanced that the removal of the two legs has to be done simultaneously. The leg should be amputated through the middle or junction of the middle and lower thirds of the thigh. As mentioned above, gangrene is as likely to set in when the femoral is obstructed as when the aorta and iliacs are. The blood to supply the flaps has to gain the profunda vessels by anastomosis. If the amputation were to be made lower, the blood from the branches of the profunda femoris would have to pass through a second set of arterioles into the branches of the popliteal and tibials. To amputate lower is to court recurrence of gangrene in the stump.

[1] *Guy's Hospital Reports*, 1857, 3d series, vol. iii., pp. 311-314, with plate.
[2] Observations pour servir a l'histoire de la claudication intermittente chez l'homme.
[3] *Brit. Med. Jour.*, 1891, vol. i., p. 639.

PLATE 8.

Gangrene from embolism.

Obstruction to the Femoral Artery and Vein.—The common femoral formerly proved a dangerous artery to ligature in continuity, and half the cases of obstruction terminated in gangrene. But by avoiding injury to the vein and septic complications it has been found that the common femoral artery can be safely ligated. A wound in Scarpa's triangle is likely to cause gangrene on account of concurrent injury to the vein and to septic complications in a patient whose general circulation has been weakened by primary hemorrhage. Although it has been found possible to ligature successfully both the common femoral artery and vein, yet this should be avoided if possible. A wound of the vein may be blocked by clot after pressure has been kept up for a short time, or a lateral ligature or suture may be applied. Should a tumor in the groin involve all three branches of the common femoral vein, it would be advisable to proceed to amputation at once rather than run the almost inevitable risk of gangrene following the simple removal. If, however, only one vein is involved, the two others are sufficient to return the blood, and the internal saphena should always be carefully preserved, not divided, in the early steps of an operation.

Obstruction to the Superficial Femoral and the Popliteal Arteries and Veins.—The superficial femoral artery and vein can be tied simultaneously in Hunter's canal without danger to the limb, and the same thing has been done with the popliteal artery and vein (Teale[1]). The success of such operations implies patency of the anastomosing vessels. But gangrene is still of frequent occurrence as a complication of ruptured popliteal aneurysm, and a number of cases have recently been recorded. As a popliteal aneurysm develops an obstruction to the blood-flow in the main artery, the anastomotic circulation through the articular arteries increases. When, however, the aneurysm grows still larger, and especially when it ruptures, it compresses the articular arteries and hinders the anastomotic circulation already established. If at this stage the superficial femoral artery is ligated, the onset of the gangrene is precipitated.

Symptoms.—The threatening signs of oncoming gangrene are as follows: The limb on exertion aches, the calf muscles become rigid and lose power, symptoms of intermittent lameness appear, which pass off with rest. The limb may become paralyzed, cold, and useless; later on the muscles atrophy. An interstitial myositis is started, causing degeneration of muscle-fibers and contracture of inflammatory tissue (Spencer[2]). Following upon ligation of the femoral in continuity, the leg may remain for days dead white, or marbled by veins, cold and insensitive; the epidermis begins to separate. Then a change comes, either in the direction of dry gangrene, or toward recovery of warmth and sensation with a development of the pink circulation beneath the toe-nails. In the former case the circulation may return, but too late; the anterior part of the foot and the toes become flushed with blood, but, the capillaries having already degenerated, the blood is extravasated in and beneath the skin.

Treatment.—Such cases of gangrene are to be avoided by early

[1] *Lancet*, 1887, vol. i., p. 12. Newbolt, *Ibid.*, 1898, vol. i., p. 1116.
[2] *Westminster Hospital Reports*, 1891, vol. vii., p. 16.

treatment of the popliteal aneurysm, and by selecting the direct operation whenever rupture has occurred. Through a posterior median incision all the blood-clot should be turned out; the articular arteries are relieved from compression, and need not be further injured. In tying the popliteal artery above and below the aneurysm, it may be possible to spare the vein.

When, however, gangrene has set in, and has spread beyond the toes, amputation should be done through the knee-joint. The articular arteries will receive enough blood from the profunda branches to supply the flaps, but the blood-pressure in them would not be sufficient to produce a passage into the branches of the tibials. To wait and then amputate lower down is to render probable gangrene of the flaps, necessitating another amputation, which even a previously strong patient may not sustain. There is no need to amputate higher than the knee unless the amputation has been delayed until septic changes have taken place and caused thrombosis of the articular arteries. To wait for a line of demarcation and spontaneous separation, when the gangrene has extended beyond the toes, is to expose the patient to much suffering, exhaustion, and septic complications, to say nothing of the delay. Even should he escape these, he will be left with a limb practically useless below the knee, always exposed to ulceration from cold or slight injury.

Obstruction to the Axillary and Brachial Arteries and Veins.—The axillary or brachial artery is liable to be obstructed by an embolus detached from the heart, the embolus commonly blocking the artery immediately below the axilla. Sudden thrombosis may occur as in Dujardin-Beaumetz's[1] case. An anemic boy of eighteen suffered from obstruction of the brachial below the axilla, no pulsation could be felt beyond this point, and the forearm and hand became gangrenous. Amputation through the middle of the humerus is necessary under such conditions, the flaps having to depend upon the branches of the subclavian and upper axillary arteries.

The veins of the arm are superficial. A tight bandage, in particular a plaster bandage, applied directly over a fracture and not removed, has caused venous congestion of the hand, then ischemic rigidity, paralysis, and even gangrene (Volkmann,[2] Leser[3]).

III. GANGRENE FROM OBSTRUCTION OF THE SMALLER ARTERIES.

Arteriosclerotic, Senile, Diabetic, and Albuminuric Gangrene.—Atheromatous and calcareous thickening of the intima in the smaller arteries is essentially a senile change, and is an especial cause of gangrene when it affects the tibial arteries. Not only does the lumen of the artery become exceedingly small, but it may at any time be obliterated by a thrombus. This senile change appears early and advances to a more extreme degree in those who have been affected by syphilis, who have taken alcohol to excess, who have suffered from overwork, hardships, or exposure. As concomitant results, there may

[1] *Bull. et Mém. de la Soc. Méd. des Hôp. de Paris*, 1875, t. xi., pp. 213, 219.
[2] *Centralblatt für Chirurgie*, 1881, p. 801.
[3] Volkmann's *Klinische Sammlung*, No. 249; *Chirurgie*, No. 77.

be found in the same patient cardiac hypertrophy and high pulse tension tending to apoplexy, chronic nephritis causing albuminuria, diabetes, obesity, and gout. The radial and temporal arteries will be hard and tortuous. One, several, or all of these conditions may coexist, to which gangrene supervenes as a late complication. The determining factor is the extent of the narrowing and thrombosis of the tibial arteries. The gangrene nearly always appears in the lower limb. It occurs, Pott said, in twenty men to one woman.

Symptoms.—The premonitory symptoms are important, for by recognizing them we may be able to ward off the gangrene. Attention is first drawn to the limb by cramping pains, numbness and cold, alternating with heat and tingling, formications, a sense of weight or of fulness, a diminution of sensation, so that a thick sock seems to be interposed between the bare foot and the floor. The patient may complain that at night sleep is disturbed by cramp followed by cold sweats. Symptoms similar to Raynaud's disease may arise, the toes may become dead and cold in the morning when getting up, or after meals. In other cases, the complaint is that intermittent lameness, obscure pains, rigidity, and paresis come on while walking, and pass off on rest. On examination the foot will be found cold, pale, and shrivelled. Pulsation cannot be felt in the dorsalis pedis and posterior tibial arteries. There is impaired sensation, the upper limit of which forms more or less of a circle round the limb and does not lie in any particular nerve-area. The diagnosis of arteriosclerosis is confirmed by finding tortuous, hard temporal and radial arteries with a high pulse tension. The gangrene generally shows first in the big toe, on the dorsum, or to one side of the nail. The skin becomes a bluish red which does not disappear on pressure. A dusky scurf or a brown horny scale is seen, or a black spot of skin, beneath which is a dusky ulcer. A blister may arise containing reddish serum, and when the covering epidermis is raised, dusky red papillæ are exposed. Some slight mechanical violence may be the exciting cause; the black spot begins where the boot has pressed on the toe, or at the site of a corn where a little cut has been made in removing it. A slight squeeze, from the toe being stepped on, or a nail projecting up from the sole of the boot, may start the gangrene. The scab may separate and the gangrenous ulcer heal, only to break down again. The ulcer may extend to the bone, causing a perforating ulcer, at the bottom of which insidious necrosis goes on. Extension to the rest of the toe and foot is marked by edema, the pitting of the skin not disappearing quickly when the pressure of the finger is relaxed; the skin of the dorsum of the foot becomes dusky red, and does not alter on pressure, but grows darker. The gangrene is usually dry; a line of demarcation forms round the toe, or at some point across the foot, or around the ankle. In a stout alcoholic patient, when once started, gangrene may rapidly spread and become moist.

Treatment.—The gangrene is prevented by exercise, massage, and baths which favor the circulation in the limb and hinder the advance of arteriosclerosis. The feet must be kept clean by bathing in warm water and drying, lest eczema be caused by dirt and sweat. Nails and corns have to be pared carefully, so that no lesion of the skin occurs. Woollen socks reaching up to the knee are to be worn both by day

and night. The feet must be kept warm by exercise, never heated at the fire, for, sensation being diminished, dangerous congestion, scorching, or burning may take place unperceived by the patient. Large well-fitting shoes are to be worn to avoid pressure, corns, and blisters. The patient's general health should be improved by the active treatment of syphilis, gout, diabetes, or albuminuria.

The circulation generally, including that of the extremities, will probably be benefited by coffee. Opium acts likewise by dilating the capillaries; it also relieves pain and tends to diminish the amount of sugar when diabetes is present. Small doses of opium are quite well taken although there be albuminuria. When the patient has taken much alcohol, the amount should be reduced to a minimum, and whenever possible stopped altogether; its place is much better filled by quinin. When a black patch appears it should be dusted with iodoform and kept quite dry. The leg and foot are to be wrapped up in cotton wool, and the patient must sit in a chair during the day with the foot raised. The foot should not be cut nor poulticed, nor soaked in hot water, nor warmed by the fire, nor by contact with a hot-water bottle. These methods all provoke the spread of the gangrene. The local conditions may favor healing; the black scab may separate and the ulcer heal; a line of demarcation may form, and the toe slowly separate. This occurs when the patient's health improves, when he is free from pain and fever, eats and sleeps well, and the sugar and albumin in the urine are reduced. On the other hand, the gangrene may gradually spread, the patient's health get worse, and some fatal complication occur, such as cerebral apoplexy, uremic or diabetic coma, or bronchopneumonia.

When the gangrene has spread to the foot and the patient is suffering from septic absorption, the removal of the gangrene becomes urgent. Even if there is not much absorption, owing to the dryness of the gangrene, yet the slowness of the separation and the pointed stump left will slowly undermine an old patient who is prevented during all this time from taking open-air exercise. Until recently removal of the gangrene was usually followed by further sloughing of the flap and necrosis of bone. This recurrence of the gangrene is independent of the aseptic character of the amputation, and is simply due to the narrowed and thrombosed tibial arteries and their branches. Amputation through the foot, ankle, or leg has been followed in a great number of cases by gangrene of the stump. A second, and even a third, amputation has had to be done, but there are very few of the patients who can survive gangrene of the flaps and reamputation. It was first proposed by Hutchinson[1] that these cases should be amputated through the lower third of the thigh, where the main artery and its branches are tolerably free from calcareous degeneration. Experience has amply proved that this is the one method of ensuring success; the rule must be "high amputation," or none at all. It has been objected to the high amputation that it causes more shock than the low amputation. As a matter of fact, the difference is not perceptible after an amputation by present methods, and the primary union which follows renders the high amputation the safer. It has been further objected that there is

[1] *Med.-Chir. Trans.*, 1884, vol. lxvii., p. 97.

an unnecessary sacrifice of limb, to which the reply may be made that the patients are usually past active work and can get about quite well enough with the shorter stump. The primary union which takes place in the thigh allows of an artificial limb being readily adjusted and easily worn.

It is hardly necessary to distinguish sharply the various cases according to their complications—senile gangrene, diabetic gangrene, etc. Old age, heart disease, bronchitis, obesity, gout, diabetes, and albuminuria, all increase the gravity of the case, but do not constitute an absolute bar to the operation. When there are both sugar and albumin in the urine to a considerable amount, the chances of prolonging life are, of course, unfavorable; but when there is only one of the two present, or one with mere traces of the other, amputation may well be successful (Küster-Heidenhain,[1] Spencer,[2] Godlee[3]). The high amputation must always be done so as to obtain primary union, there should be no loss of blood beyond that in the limb at the time, and antiseptics like carbolic acid or perchlorid of mercury should not be used except for the skin, lest absorption take place. Experience has shown that along with the healing of the stump the albumin or sugar, or both, have fallen to a small amount. In many cases of chronic albuminuria or diabetes life has been much prolonged by this amputation. The bad results formerly obtained when the urine contained albumin or sugar were due either to the operation being septic or to the insufficient blood-supply in the stump. Before performing the high amputation the surgeon can convince himself of the correctness of the diagnosis and treatment by cutting across the tibial arteries, when they will be found scarcely to bleed at all. It need hardly be added that amputation through the knee-joint is less suitable; owing to the long thin flaps supplied by the popliteal articular arteries, which may be partially sclerosed, the amputation-flaps should depend upon the branches of the femoral for their blood-supply.

Gangrene due to Arteritis Obliterans.—Arteritis or endarteritis obliterans is the name given to a fibrous thickening of the internal, and to a less extent of the middle, coat of the smaller arteries. If it progresses far enough, the lumen of the vessel may be practically obliterated, and the larger arteries on the proximal side undergo thrombosis; and hence, if the disease attacks the vessels of the limbs, gangrene may follow.

Obliterative arteritis is best known from its occurrence in the sylvian, vertebral, coronary, and pulmonary arteries, the increase of fibrous tissue being generally concentric, less often eccentric, causing the appearance of a nodule on one side of the artery. The affection of these arteries is without doubt due in many cases to syphilis, but there does not seem to be any special microscopic lesion distinctive of syphilis. If one can conclude from the failure of antisyphilitic remedies in such cases, one may look at the lesion as a post-syphilitic one. But physicians are generally disposed to admit that obliterative arteritis may occur in patients who have not had syphilis or indulged in alcohol.

[1] Küster's cases. Vide Heidenhain, *Deutsch Med. Wochenschrift*, 1891, S. 1087.
[2] *Med.-Chir. Trans.*, 1892, p. 395.
[3] *Ibid.*, 1893, p. 37.

Friedländer[1] compared the thickening of the intima to that which causes the obliteration of the ductus Botalli, the hypogastric arteries, and those of the uterus during involution after pregnancy.

In the group of cases to which attention is here drawn, the obliterative arteritis has affected the vessels of the limbs and threatened, or actually produced, gangrene. The cause is quite obscure, a history of syphilis or of alcoholism being distinctly absent. Clinically the cases are to be distinguished by the absence of heart disease or of any previous illness likely to originate embolism or thrombosis. The patients are not affected by atheromatous disease or calcareous degeneration causing arteriosclerosis, for they are young adults, presenting no senile changes, no tortuous temporal nor radial arteries; the affected vessels simply feel like a cord. The disease is not attended by albuminuria, cardiac hypertrophy, nor excessive pulse tension in the patent vessels. In Raynaud's gangrene, to be described later, there is spasm of the arterioles, not a change in the vessel-walls.

The case of arteritis obliterans described by Pearce Gould[2] has been under observation for a long time. The patient presented peculiarly characteristic features; the disease occurred in a young adult, in the absence of the known causes of arterial disease; it progressed for a time, was then spontaneously arrested, and was followed by a restoration to health, which has been maintained for a period of years.

A man, nineteen years old when first seen, worked in a brick-field, but had not been exposed to wet and cold. When aged twelve he had suffered from scarlet fever complicated by dropsy and convulsions, as many as 45 fits occurring in a day. From this he apparently quite recovered. When thirteen he had a whitlow on the right little finger; at seventeen he struck his right fifth metacarpal bone and a thickening resulted. He was a teetotaler, and had never had venereal disease. He first noted that the fingers of the right hand became dark, then that the right hand and forearm became cold, weak, and painful whilst at work, so that he was forced to stop, but after an hour's rest the hand became warm again. When first seen, the brachial artery pulsated down to a point just above the elbow, below which it formed a pulseless cord. Whilst under observation the pulse in the brachial gradually disappeared as far up as the axillary artery, but the superior profunda artery could be felt above the outer condyle of the humerus. Dry gangrene attacked the ends of the thumb, middle, and ring fingers, and the dead parts were later on removed. No other lesion was found. He was seen again when aged twenty-two; the third part of the right subclavian, the axillary, and the arteries below formed cords without pulsation. No further gangrene had appeared. The man was heard of again when thirty years old; he was well and doing all his work.

Hadden[3] described a similar case in a young woman.

The following is the brief account of a more advanced case under the writer's care:[4] An omnibus driver, aged twenty-seven, had had no previous illness except that, eleven years before, he had had gonorrhea and sores which lasted nine weeks. No signs of syphilis followed. He was married and had two children. His urethra was found on examination to be normal. He had not taken alcohol to excess. His mother and two brothers had died of phthisis and a sister was suffering from her chest. He had noted that for three months—July, August, and September—his left foot had at times become cold, so that he had frequently to rub it in order to keep it warm. He also had a sore on his little toe, which healed and then reappeared three weeks before he was first seen. Then followed a change in the color of the left foot to a bluish red. It became very painful, especially at night, across the base of the toes, and a black spot appeared on the great toe. When first seen, dry gangrene had affected the great and little toes and threatened to set in on the instep and skin of the leg. No pulsation could be felt in the left thigh and leg, a hard cord being felt in the position of the femoral artery; the veins were unobstructed. The right foot was cold and damp, but not painful. On the plantar surface of the ungual phalanx of the great toe was a superficial dusky patch. No pulsation could be felt, and the right femoral artery formed a cord. No pulsation nor sound could be clearly heard in the abdominal aorta nor

[1] *Centralb. f. d. med. Wissenschaften*, 1876, S. 64.
[2] *Clinical Society's Trans.*, 1884, p. 95; 1887, p. 252; also note given to writer.
[3] *Ibid.*, 1884, p. 105.
[4] *Ibid.*, 1898, p. 89.

in the iliacs. The right hand was colder than the left, the right axillary and brachial smaller, the radial artery very small, but soft and not tortuous; the ulnar artery could scarcely be felt. The arteries of the left arm were normal, the pulse being of low tension. The temporal arteries were likewise soft, not tortuous, and the pulse in them was of low tension. The heart, lungs, and urine were normal. Under observation the pain in the left leg increased. At times there were paroxysms of cramps, when the calf muscles became hard and tender. The opium he was given had gradually to be increased to 1 grain (0.065 gm.) of ext. opii every four hours, besides which as much as three injections of $\frac{1}{2}$ a grain (0.0324 gm.) of morphin were required during the day. In spite of the narcotic he got but little ease or sleep, he was generally half-sitting, looking at his leg with an anxious expression, and sweating. He became thin and his pulse weaker. During the week before the amputation dry gangrene began in the skin of the instep and of the front of the leg; the temperature arose, the highest point being 101.2° F. Amputation was done through the middle of the left thigh. At once all pain was lost, he recovered his appetite, slept well, the general circulation improved, but there was no increase of pulsation in the obstructed arteries. The right hand and foot became warmer, and the right foot freely desquamated. A year later the patient was well and had returned to his former employment. At the amputation the femoral artery was found blocked by a firm clot, and the proximal cut end did not pulsate on removing the elastic band. Besides the femoral vein, which was patent, only one small artery near the sciatic nerve was tied; there were no other bleeding points and very little oozing. In the amputated limb the popliteal and its bifurcations were filled by a firm, laminated clot. The endothelium and the intima within the elastic lamina had blended with the clot, otherwise there was no obvious change in the vessel-wall. The lower part of the tibials was thickened but empty, the lumen being smaller, and this was most marked in the lower end of the posterior tibial and in the plantars. The narrowing was caused by a fibrous thickening of the intima. Where less marked the fibrosis was internal to the elastic lamina, which was unaltered; where the disease was more advanced the elastic lamina had been replaced by fibrous tissue, and there was some invasion of the middle coat. This thickening of the intima was eccentric, not concentric; in one quadrant the thickened intima projected into the lumen, the rest of the circumference being altered little or not at all. The intima of the corresponding veins was also slightly affected. The arterioles in the substance of the calf muscles were unchanged. Other cases in which gangrene has followed arteritis obliterans have been seen in older patients, but it may be questioned whether they are not essentially different from those just described, and whether such cases have not features more nearly allied to arteriosclerosis, thrombosis, etc., included under previous sections of this article. In Winiwater's[1] case gangrene attacked the foot of a man aged fifty-seven. In the posterior tibial artery and vein of the amputated limb was found an endothelial and subendothelial proliferation, with the development of blood-vessels in the media and intima. The media and adventitia were also affected, but to a less extent than the intima. The patient had not had syphilis. In one of Widenmann's[2] cases a man of sixty-five was attacked with moist gangrene of both feet simultaneously, attended by high fever. He had also marked emphysema and bronchitis, tuberculosis of the lungs, and a dilated heart, but no sugar nor albumin in the urine. He had not had syphilis. The vessels were not tortuous. Post mortem there were found in the tibials a marked concentric thickening and vascularity of the intima, the media was thickened, and in it some lime salts were deposited; the adventitia was also infiltrated. The lumen was occupied by organized thrombi, and there were thrombi in the veins. In another case amputation of the arm was done for moist gangrene, which had begun suddenly fourteen days before, after an attack of influenza. The man, aged forty-nine, had no sugar nor albumin in the urine, nor had he had syphilis. The stump bled freely and 30 ligatures were used. The arteries of the amputated limb were thrombosed, their coats not much altered; there was marked thickening of the intima in the smaller veins.

IV. GANGRENE FOLLOWING ON SPASMS OF THE ARTERIOLES.

The ends of the fingers and toes, the tips of the ears and of the nose suffer from the intermittent occurrence of pallor, cold, and numbness due to arterial constriction, followed by redness, heat, and tingling owing to arterial relaxation. Thrombosis supervenes on prolonged constriction and blocks the small veins and capillaries, and this is shown by dusky redness which does not disappear on pressure. Recovery may take place after superficial desquamation or ulceration. The thrombosed tissue may slowly die, causing gangrene of the dry kind.

[1] *Archiv f. klin. Chirurgie*, 1878, Bd. xxiii., S. 202.
[2] *Beiträge z. klin. Chirurgie*, 1892, Bd. ix., S. 218.

Gangrene from Cold.—Chilblains.—A slight degree of thrombosis produces ulcerated chilblains. They commonly appear in anemic, badly fed children, whose hands and feet are not kept warm and dry and whose shoes pinch the feet. Patches on the fingers and toes are white and ache; on being warmed, the skin turns red and itches. When thrombosis occurs the spot becomes dusky red and forms an ulcer from which a slough separates. Chilblains are in many instances precursors of Raynaud's gangrene.

Chilblains are avoided by good food, by daily exercise, by woollen socks and gloves worn night and day in winter, with roomy, good-fitting shoes. The hands and feet are not to be put suddenly into hot water nor warmed before the fire. Lukewarm water is to be used for washing, after which the hands and feet are to be rubbed dry. A chilblain which has formed and threatens to ulcerate should be painted with iodin tincture. When ulceration has taken place, a mild antiseptic ointment is applied.

Frost-bite.—When the circulation is restored after pallor caused by cold, there are bright redness, heat, and tingling. When, on account of the prolonged cold, thrombosis is set up, there are dusky redness, loss of warmth, and numbness. Frost-bite is systematically avoided in cold climates by keeping the extremities warmly covered. The cap covers the ears, large gloves without fingers the hands, extra large boots are worn, so that the feet can be encased in thick wool stockings or bands of hay. The tip of the nose is exposed, but this is not in danger unless there is in addition to the cold a damp and high wind. But when predisposing influences come into play, frost-bite may occur although the temperature is above freezing point. Frost-bite is favored by alcohol on account of the greater loss of heat from the surface, also by fatigue and want of food. A man who has plenty of food, who avoids fatigue and alcohol, may sleep out on the snow without harm, whilst a drunkard asleep on damp, unfrozen ground may suffer. Loss of blood favors frost-bite; hence the wounded lying out at night after a battle are liable to be attacked.

Treatment.—A patient affected by cold and threatened with frost-bite should be taken into a room of the ordinary temperature, but should be kept away from the fire. The threatened extremities are rubbed with snow or cold water, not plunged into warm water, until the circulation improves; they are then well dried and wrapped up. The patient is given hot soup and coffee, but not alcohol, except in very small amounts. If unconscious, hot nutrient enemata, with or without brandy, are administered, and plenty of covering put on the bed, until warmth and consciousness return. A part becoming gangrenous is dusted with iodoform under a thin layer of wool. The gangrene will be dry, and generally the slough may be allowed to separate spontaneously; at least, no operation is permissible until the patient has recovered from the general effects of the cold. The operation is usually limited to the removal of the bone from the pointed stump, so that the skin-flaps can heal. Moist gangrene and septic infection are unlikely to happen, unless the already gangrenous limb is kept hot and moist.

The artificial cold produced by the ether spray has given rise to gangrene. A nodule in the skin was removed under ether spray from

PLATE 9.

Harrington's case of carbolic gangrene.

the leg of a woman aged seventy; gangrene spread from the wound and caused death. It is therefore a good rule not to freeze the skin of old people.

Carbolic-acid fomentations have caused gangrene of the fingers, therefore boric acid, not carbolic acid, should be used for fomentations (Péraire [1]).

Gangrene due to Ergot.—Ergotism is the result of eating bread made from rye affected by the fungus, especially when 1 grain in 8 or 10 has been so diseased. It is met with, therefore, only in those who have lived upon such bad bread, and the severity of the disease depends upon the amount taken. The rye is attacked by the fungus in cold, wet summers, and gangrene from ergot could not be seen nowadays except among peasant farmers in districts unfavorable for agriculture, where the farmers are forced to eat the grain they cannot sell. The disease has been met with during the last two centuries in France and Germany, not in the British Isles, where rye is hardly ever, or never, used for bread. Ergotism was reported from France during the year 1897 (Mongour [2]). Ergot is produced in America, but ergotism does not seem to have appeared. Ergot causes gangrene chiefly in middle-aged men, much more rarely in women, its incidence in this respect resembling that of gangrene due to arteriosclerosis. Children suffer, both male and female, but less often than men, the convulsive form of ergotism being more marked. But there must be some special predisposition which accounts for the differences in susceptibility among members of the same family similarly exposed to the influence of the poison.

Although ergot has often been administered in large doses for long periods, the drug has never been known to cause gangrene. It may therefore be supposed that the gangrene is the combined result of ergotized bread and insufficient food. The gangrene is the consequence of long-continued vascular spasm leading to thrombosis. The earlier symptoms of ergotism are due to constriction of the blood-vessels of the central nervous system and of the intestine: they are giddiness, disturbances of vision from a peculiar sensibility of the retina, buzzing in the ears, formication, itching, and hyperesthesia of the skin; hence the German name "Kriebelkrankheit." The next series of phenomena are due to spasm of the muscular arterioles causing painful creeping and burning cramps; from these burning sensations originate the French name "Mal des Ardents," and the old English one "St. Anthony's fire."

The gangrene is generally dry and symmetrical, and affects mostly the feet, although the fingers, ears, and nose have been attacked. The gangrene does not prevent the patient from getting about; men have been seen walking on the dead limb as on an efficient stump. The period of separation is a prolonged one, two years or more, and it usually takes place at one of the joints of the foot or at the ankle. The line of demarcation may form higher up, and extreme cases have been recorded in which both legs sloughed off at the hip-joint (Salerne [3]). The main arteries are thrombosed and occluded early, so that there is no danger of hemorrhage.

Treatment.—The earlier symptoms of the ergotism being present,

[1] *Centralbl. f. Chirurgie*, 1896, S. 783. [2] *Arch. clin. de Bordeaux*, 1897, t. vi., p. 325.
[3] Vide Duplay et Reclus, *Chirurgie*.

gangrene may be prevented by good food, warmth, friction, with coffee and opium for the cramps. The gangrene is treated expectantly, any surgical interference being put off until the patient's general health is restored, and is always of a very limited character.

Lead acts in a similar way to ergot and is said to produce gangrene, or rather to increase the ill effect of other causes, such as arteriosclerosis (Sainton [1]).

Raynaud's Gangrene.—Raynaud's gangrene is that form of gangrene which results from a prolonged continuance of Raynaud's symptoms, the characteristic feature of which is a generally symmetrical and paroxysmal spasm of the arterioles, of nervous origin.

Raynaud's gangrene should not be extended to be synonymous with symmetrical gangrene, for the symmetry may be due to thrombosis. Indeed, Raynaud's symptoms are frequently unilateral, even limited to the distribution of a single nerve. Neither is Raynaud's gangrene the only kind that is preceded by paroxysmal symptoms, for both obstruction to main blood-vessels and arteriosclerosis of the tibials are attended by intermittent paroxysms which gradually lead on to gangrene. There is no doubt that Raynaud [2] included in his original essays cases of gangrene whose pathology widely differed. The term "Raynaud's gangrene" should be applied to those cases in which there is no obstruction of the main arteries, nor arteriosclerosis, the onset of which is preceded by characteristic symptoms.

At least two well-marked types are met with. One occurs in anemic women and others in feeble health, including lunatics, or in those exhausted by disease, such as ague, all with a feeble pulse of low tension; the treatment of this type is practically that of the anemia. The other and less common type occurs in young people about puberty, both male and female, and is characterized by a pulse of high tension, and by arteries hypertrophied, hard, and tortuous, so that they can be rolled beneath the fingers. Such patients are liable to the complications ensuing from this high pulse tension—viz., hemoglobinuria, purpura, apoplexy and other hemorrhages, and uremia (Aitken,[3] Osler [4]). The spasm of the arterioles is supposed to originate in some blood-disease causing excessive destruction of the blood-corpuscles; hence the excitation of vasoconstrictors, accompanied by a special sensitiveness to changes in temperature, and neuroses of various kinds. Raynaud used two words in a special way, "local asphyxia" and "local syncope." He applied the term "asphyxia," in its literal sense of "want of pulse," to the dead-white finger, but owing to a confusion with the commoner use of the word in connection with carbonic-acid poisoning, it has been used by some writers for the subsequent stage of venous congestion. Raynaud called the local bloodlessness "local syncope." But the patients are often anemic and have feeble hearts, and so are liable to fainting. Hence it is difficult to understand, in reading the accounts of some writers, whether they are alluding to the

[1] *France Méd.*, 1881, t. xxviii., p. 221.

[2] *New Sydenham Society*, 1888, vol. 121. Raynaud's two essays on local asphyxia, translated by T. Barlow.

[3] *Lancet*, 1896, vol. ii., p. 875.

[4] *Am. Jour. Med. Sci.*, 1896, vol. cxii., p. 522.

local spasm in a limb, or to syncope produced by an insufficient blood-supply to the brain.

Symptoms.—The earliest of the Raynaud's symptoms is the dead white finger; less commonly the toes, the tips of the ears, or the end of the nose are affected. The finger is cold, bloodless, yellowish white, insensitive and powerless. The attacks occur at meal-times and during digestion, whilst getting up in the morning, and also when tired. The spasm is followed by relaxation, venous congestion, and warmth. The color is then lilac or slaty blue, and, if the fingers are put into hot water, becomes almost black. During the reaction there are pains described as stinging, burning, and shooting; occasionally the affected fingers are covered with a cold sweat and patches of red congestion; erythromelalgia or red neuralgia and patches of edema occur. The attacks are not always worst in winter, but often in spring and autumn. One of Raynaud's cases suffered most during the heat of summer, when working in the sun.

When gangrene threatens, recovery is incomplete between the paroxysms, the skin becomes hard like parchment, the color becomes drab or bronzed, gradually violet, and finally black. The local venous congestion must be distinguished from the congenital blue of morbus cæruleus, consequent on a patent cardiac septum. A case is recorded in which cyanosis from this cause was later on complicated by Raynaud's gangrene.

Small blisters with a seropurulent fluid may form. There may be excoriation and desquamation of the skin. Raynaud's gangrene has occurred in several cases along with scleroderma; sometimes one has appeared first, sometimes the other (Chauffard,[1] Hutchinson[2]). Paroxysmal attacks of hemoglobinuria and of purpura have complicated Raynaud's gangrene. Cases have died of apoplexy and of uremia where the pulse has previously been of high tension and the arteries hypertrophied.

As regards the **treatment** of Raynaud's symptoms threatening gangrene, the anemia is treated by iron and arsenic; quinin also has acted well as a tonic, especially where the patient has had ague. The local treatment consists in shampooing with warm salt water. The paroxysms are relieved by warm water, but are made worse by hot water; sometimes cold gives more relief, but it should be applied for a short time only. Opium may be given for pain. The patient should be protected against cold, as mentioned under the head of Frost-bite. Separation is allowed to go on spontaneously, any cutting away being confined to the dead part.

V. GANGRENE FROM OBSTRUCTION TO CAPILLARIES AND SMALL VEINS.

The feature characteristic of this class of gangrene is the obstruction to the blood-flow through the capillaries and venules, although the tendency to gangrene may be indefinitely increased by failure of the general circulation, by obstruction to the main artery, or by pre-

[1] *Gaz. des Hôp.*, 1895, t. lxviii., p. 818.
[2] *Archives of Surgery*, 1896, vol. vii., p. 201.

viously existing arteriosclerosis. The capillaries and small veins are obstructed as a direct result of the injury, *simple traumatic gangrene*, or by an inflammatory septic thrombosis, which may appear as a complication and extension of the former, *spreading traumatic gangrene*.

Simple Traumatic Gangrene.—A burn chars the tissues and stops the circulation. A crush smashes the tissues and produces an extravasation of blood which compresses and arrests the blood-flow in vessels not directly injured. A bullet entering through a small hole causes a destruction of tissue and an extravasation of blood depending upon its velocity and the size of the blood-vessels met with. The modern rifle bullet of high velocity may produce an "explosive" effect, widely smashing and destroying the tissues in its course. As a further consequence of severe injury, the general circulation is weakened by shock and by loss of blood.

Treatment.—On careful examination of the threatened part, the circulation may be found absolutely stopped. Even when incisions are made into it, there is no oozing from the cut arteries. The treatment consists in removing the dead part as soon as the patient has recovered a little from the shock of the accident, and before decomposition has set in.

Whenever it is found that the threatened part is still connected with the rest by some uninjured tissue, it is always possible that an anastomotic circulation may be set up as the general circulation recovers from the shock of the accident. At the same time it is necessary to remove any compression on the still unimpaired vessels by turning out extravasated blood-clots, by reducing fractures and dislocations, and removing foreign bodies. All septic material should be removed from the wound. As soon as possible after the accident the patient is to be laid at rest, hot fluid food or enemata are administered, and he is well covered up with blankets and hot-water bottles until he becomes warm and begins to sweat. A burn is covered with dry antiseptic dressings, and as soon as the dead tissue can be distinguished from the living, the former is cut away, or it is partly raised and strips of iodoform gauze are slipped beneath, so as to protect the living tissue from the products of decomposition of the dead tissue. In the case of a compound fracture or bullet-wound, the area of injury is fully exposed under an anesthetic, the skin orifice being extended by incisions as necessary. All the pockets are cleared of blood-clot; foreign bodies, bullets, etc., are removed; splinters are replaced in position, and the fractured ends of bones and dislocated joints reduced and, if necessary, fixed by sutures or pegs. Every part of the wound is freely swabbed by 5 per cent. carbolic acid or other antiseptic, the antiseptic being finally swilled away by pure water. If the hemorrhage has had to be controlled, the tourniquet is now released and all the bleeding points ligated. One or more strips of gauze are laid in the wound to act as a drain, and the limb is wrapped up and placed in a position favorable for the return of venous blood, which must not be hindered by a tight bandage. With this treatment soon after the injury there is no danger of spreading gangrene. The removal of causes of compression allows collateral circulation through the still uninjured vessels. Even if gangrene should happen, the delay is not dangerous, owing to

the antiseptic treatment applied to the wound. The patient will be better able to stand the amputation, and, if the circulation returns in part, the secondary amputation may be more limited than would have been the primary one.

In old people the circulation is often poor, owing to previous arteriosclerosis, and so in them gangrene is more likely to follow an injury. They may be less able to undergo the strain of the repair of an injury than that of the amputation. Moreover, the loss of the limb may not be so important as to a younger patient. These latter considerations will point toward primary amputation for old people. Primary amputation may still have to be largely adopted in war-time, when the means of treating the wounded are of an inferior kind. In amputating for traumatic gangrene the state of the skin-flaps requires attention, for although the level of amputation be above the injury to the main blood-vessel, if the skin from which the flaps are cut has been bruised, sloughing may take place. Only strong patients can be expected to survive sloughing of flaps and reamputation. If, therefore, when cutting the flaps the small vessels are found already thrombosed, a higher level should be selected.

Septic or Inflammatory Gangrene.—The characteristic feature of this variety of gangrene is the obstruction of the capillaries and the small veins of the tissues by thrombi containing micro-organisms which rapidly multiply and spread the thrombosis, and so the gangrene. Anthrax bacilli multiply at the site of the inoculation, and the capillaries and veins become blocked by masses of bacteria. An eschar forms at the center, and around it is an inflammatory zone in which the thrombosis is going on, although the arterial circulation is not yet at a standstill. Similarly, a boil or carbuncle commences by a septic thrombosis at the center, which causes an arrest of the circulation and a central slough surrounded by an inflammatory zone.

Spreading Traumatic Gangrene.—The amount of injury varies from a mere prick or scratch up to an extensive laceration, but the essential feature is the septic inoculation. In some cases the injury may be so slight as a prick from a thorn, a scratch from an instrument, the sting of an insect, or the inoculation of septic material through a previous abrasion. In other cases there may be a serious contusion, a compound fracture, a gunshot wound, the bite of an animal, a crush by machinery or on the railway, and the septic inoculation is then a complication of a lacerated wound.

Symptoms.—The marked sign of spreading traumatic gangrene is advancing dusky edema. Within a day of the accident the edema may have spread from the injured hand or foot to the forearm or leg; in two days or so it may have almost reached the shoulder- or hip-joint. The patient is meanwhile much affected by septic absorption, soon becomes delirious, and has a rapid pulse and respiration. The temperature is untrustworthy: it may be high at first and then slowly descend to be little above the normal, or it may even become subnormal when the patient is exhausted. Commencing gangrene is shown by the bullæ containing stinking greenish serum which form on the dusky edematous skin. On separation of the epidermis, the dermis beneath appears of a greenish yellow. The skin crackles when touched, owing to septic

emphysema. On cutting into the limb, abscesses containing stinking pus and gas are found in all directions. Within two days the gangrene may have extended from the hand or foot to the elbow or knee. Very soon the septic edema spreads from the limb to the trunk, and behind it follows the gangrene.

The only **treatment** is prompt amputation above the edematous zone, and removal of the arm at the shoulder-joint or of the leg high up in the thigh has saved life in many cases. If the flaps are at all affected by dusky edema or by septic thrombosis, this will be perceived in cutting them. If there is some edema and it be deemed inexpedient or impossible to cut a flap higher up, iodoform gauze should be laid in the wound, between the flaps, and then a limited ulceration of the flaps will not so greatly affect the patient. If after a day the flaps appear quite healthy, secondary sutures may be used. The administration of streptococcus-antitoxin may be of advantage as an adjuvant to the surgical measures, but only when streptococci are the chief organisms found (Steele[1]).

Cutaneous Gangrene.—This form of gangrene is set up by the micro-organisms causing erysipelas, or similar streptococci, in patients previously weakened by disease. An acute attack of erysipelas may go on to gangrene of the skin, especially of the scrotum. Infants and children who have suffered from one of the specific fevers are liable to be attacked, multiple patches of gangrene developing on the skin, especially of the abdomen. The patients have generally been much exhausted, and there is great failure of the circulation. Yet some of the worst cases of multiple cutaneous gangrene have followed chicken-pox in which the child has suffered beforehand but slightly. In old people, multiple gangrenous patches may appear when many of the vessels have been partly obstructed by arteriosclerosis.

Symptoms.—The first sign of cutaneous gangrene is a red blush with slight inflammatory induration. The color quickly becomes dusky and ceases to disappear on pressure; sensation is lost, and the patch soon becomes gangrenous. Several of these patches appear simultaneously, or one after the other within a day or two.

Treatment.—The only specific general treatment is the injection of antistreptococcic serum, and the more clear the erysipelatous origin, the more likely the success. Locally an erysipelatous patch may be painted with iodin or nitrate of silver, with the view of increasing the circulation by counter-irritation and so preventing thrombosis. Whenever thrombosis and loss of sensation preindicate gangrene, the skin should be raised by an incision and a strip of gauze slipped beneath. This gives any skin in which some circulation is still going on the best chance of recovery, while it anticipates the collection of foul pus beneath the slough. As soon as the outline of the slough is determined, it is cut away.

Cancrum Oris; Noma of the Vulva; Gangrene of the Umbilicus.—Children exhausted by scarlet fever, measles, and other specific fevers, by bronchopneumonia or general neglect, are liable to be attacked by gangrene which commences in the mucous membrane of the mouth, on the vulva in female children, and at the umbilicus of

[1] *Brit. Med. Jour.*, 1896, vol. ii., p. 1768.

infants. It is distinguished from the cutaneous gangrene by rapidly burrowing into the deeper structures, and by commencing in some excoriation or ulcer. The onset is insidious, there being only a small superficial slough, beneath which the septic thrombosis and gangrene rapidly go on. Moreover, the child does not complain of pain, does not cry, and the appetite persists. It becomes more and more dull and sleepy, without any marked rise of temperature, then delirious, and the pulse and respiration increase in rate. The first sign to attract attention is often the foul smell; then a grayish patch will be found, surrounded by a brawny zone. On exploration, stinking sloughs are brought to light. In cancrum oris the cheek may be rapidly perforated or destroyed, the lower jaw becomes necrosed; or the upper jaw may be similarly affected and the antrum filled with pus. The swelling of the cheek, in the absence of striking symptoms, may be at first mistaken for alveolar abscess. The child may die of septicemia, or develop septic pneumonia, or the gangrene may spread to the neck first.

Noma may extend rapidly on the vulva, causing a deep sloughing ulcer, which spreads toward the pubes, bladder, or rectum. A similar form of gangrene is occasionally seen in the scrotum of little boys.

Gangrene of the umbilicus is common amongst the poor of hot climates; it rapidly extends to involve the whole thickness of the abdominal wall, and finally the peritoneum, if the infant lives long enough.

Treatment.—The occurrence of such cases is prevented by care during convalescence, by attention to thrush or carious teeth. Systematic cleanliness is required to avoid excoriations about the umbilicus and genitals. Immediately cancrum oris is recognized by the foul smell, grayish slough, and brawny induration, active treatment must be adopted. A little chloroform is generally given, unless there is marked drowsiness, when chloroform is not only superfluous but dangerous. The head must hang low, so that no slough may be inhaled, and the mouth well opened by a gag. Then as much as possible of the slough is cut or scraped away until vascular tissue is reached, without going far enough to excite severe hemorrhage. This may include the removal of the alveolar portion of the upper or lower jaw, if it is dead. Then the walls of the cavity left by removing the slough are scrubbed with pure carbolic acid or 0.5 per cent. (2 : 1000) perchlorid of mercury. Care should be taken not to use an excess of the antiseptic, to guard the throat by a sponge on a holder, and to keep the head low. All the antiseptic is finally washed away with water. The actual cautery may be used instead, merely searing, not charring, living tissue. There is no need to apply fuming nitric acid, since its application is much more difficult, and it penetrates deeply and causes more pain without being more efficacious than the carbolic acid or sublimate. A gangrenous patch involving the tonsil of a child was checked at once by applying pure carbolic acid. Iodoform gauze is used as a dressing, along with frequent irrigations of permanganate of potash. Alternately, cavities are filled with gauze saturated with 1 or 2 per cent. of the permanganate. Portions of the lost jaw may be later on replaced by new bone; a perforated cheek, or one in which the jaw tends to become closed by the contracture of scar-tissue, is repaired by

plastic operations. Gangrene of the vulva may lead to severe hemorrhage, necrosis of the pubes, etc. It is treated as above, the resulting cavity being well plugged. An infant is not likely to survive gangrene of the umbilicus, but it should be treated promptly, in the way above described, to prevent perforation of the peritoneum.

Phagedena—Hospital Gangrene (see Chapter VII.).—This form of infectious gangrene is now most frequently seen as a complication of venereal disease and of ulcerated legs, and is under the former circumstances transmitted by direct inoculation. The glans may be destroyed, or a part or whole of the penis, and the skin of the scrotum. It may extend back through the perineum and perforate the rectum. In the female it may spread to the bladder. If it attacks a suppurating bubo, the ulcer may quickly perforate into the large blood-vessels. A phagedenic ulcer of the leg commences to extend rapidly round the leg and excavate more deeply, so as to expose the bone.

Phagedena is probably caused by a special bacillus inoculable on human beings.[1] The surface of a wound becomes covered with grayish-green sloughs and stinking pus. It is often a mixed infection, erysipelatous gangrene rapidly extending in the neighboring skin and tissues.

If phagedena is threatening, the sore should be painted with pure carbolic acid. In a marked and extending case the patient is anesthetized, and all the slough scraped away. Then pure carbolic acid is well rubbed in; finally all the carbolic acid is washed away with pure water. The pure carbolic acid will arrest the phagedena at once; it does not penetrate the healthy tissues, and owing to its analgesic properties causes little pain. Caustics like nitric acid, caustic potash, arsenic, or chlorid of zinc are difficult to limit and give much pain. The actual cautery may be used, as it can be exactly applied; but it should sear, not char. The ulcer is dressed with iodoform gauze, with gauze wrung out of 1 or 2 per cent. permanganate, or by boric-acid fomentations, to which opium may be added to relieve pain.

Bed-sores, or Decubitus.—A bed-sore is a gangrenous ulcer to which a patient whose circulation is weak is liable owing to continual pressure and to the irritation of the skin by dirt and sweat. It is nearly always due to the absence of proper medical attention and nursing. The older and more helpless the patient, the greater the liability to bed-sores. They are the most difficult to prevent in the delirious, the paralyzed, and the insane. Yet no bed-sore of an extensive kind can be looked upon as inevitable. Paralysis due to injury or disease of the spinal cord is not necessarily followed by bed-sores. Public infirmaries and asylums now record the number of bed-sores which occur, and, owing to the advance in the standard of nursing, the number of bed-sores in such institutions is becoming a vanishing quantity.

Bed-sores occur on the sacrum or buttocks owing to pressure in the dorsal position, over the great trochanter from lying on the side, over the anterior iliac spine, knee, dorsum of the foot, etc., from the pressure of the bed-clothes. Bed-sores are seen higher up on the spine or between the shoulders when the spine is curved or when there is a ridge in the bed. Sores may be seen over the elbows or even over the

[1] Vincent and Cayon, *Annales de l'Institut Pasteur*, 1896, t. x., pp. 489, 661.

occiput from unduly resting on these bony prominences. Sores appear on the point of the heel, over the malleoli, or on the side of the knee or elbow from the pressure of a splint. The upper end of the splint may press on the patient's buttocks, into his fork, or into his armpit, and so cause a sloughing sore.

The prevention of bed-sores is an essential part of good nursing. The bed should be made with a firm smooth mattress, not a feather-bed; the under sheet and blanket must be changed before they are saturated with sweat. The draw sheet is spread free from creases, depressions, or prominences, and foreign bodies, such as bread crumbs, are kept out. But the great preventive is the washing of the places liable to pressure with hot water, soap, and flannel or sponge, laving with clean water, and completely drying with a smooth warmed towel. Most weakly patients confined to bed require such a washing twice a day, and it may have to be done much oftener, indeed, every three hours. The urine, feces, and discharges from wounds should be absorbed before the bed is soiled. The urine of a man can be received

FIG. 52.—Bed-sores in a case of fracture of the spine.

into a flask-shaped urinal, that of a little boy into a smaller vessel, such as a large test-tube. Urine coming through a perineal wound or from a female with incontinence is received into a pad of wool or compressed moss, which must be changed before it is saturated. Incontinence of urine may be much relieved by aseptic catheterism and irrigation of the bladder. The feces should be removed as soon as passed, by anticipating the patient's need for the bed-pan, by regulating the bowels with aperients, by administering a cleansing enema daily to remove scybala, and, when there is complete incontinence, by frequently changing the pad receiving them. As supplements to hot soap and water, but by no means as substitutes, turpentine or ether may be used to aid in removing excess of sweat and dirt; lotions of lead acetate, of zinc chlorid, of silver nitrate, or of spirit harden the skin. After complete drying, a dusting powder of zinc oxid and starch may be applied, but irritating cakes will form if there is any moisture.

A prostrate patient requires to be frequently turned to one side or the other; young people may be even turned on to the face. Pressure

is also taken off by pillows, air-cushions, and water-beds of various kinds.

The surgeon also has to direct his attention to avoiding bed-sores. He has to see that the nurse is assisted in turning, lifting, and cleaning the patient, especially when he is heavy, and an arrangement with pulleys may be needed. The surgeon must also modify his treatment of the patient with this object; ill-fitting plaster jackets or splints should be changed; a child with hip-joint disease must have both legs fixed on side-splints (Hamilton's) sufficiently wide apart to be easily cleaned; an old woman with an intracapsular fracture of the femur should be got up into a chair in spite of there being no union.

Signs and Treatment of a Bed-sore.—The skin fails to quickly regain its normal color when pressure is released. Instead, it is of a dusky red which does not disappear under the finger pressure; the skin feels rigid and thicker than normal. The epidermis becomes detached, exposing the papillæ. At this stage recovery is still possible. If the unfavorable conditions persist, the skin becomes gangrenous. If the part pressed on is first rendered anemic, the slough is grayish white; if there is beforehand the dusky red of venous congestion, a greenish slough forms. When gangrene has not definitely set in, the treatment above noted should be continued, and it may serve to limit the extent of the bed-sore. But when the skin is clearly dead, the sooner it is cut away the better, after which the sore is frequently washed, and dusted with iodoform and dressed with gauze. Should there be any sign of phagedena, pure carbolic acid may be painted on. The frequent antiseptic dressings should produce a healthy granulating surface, and then the ulcer, if large, may be covered in with skin-grafts. If, after the removal of the sloughs, granulations are slow in forming, astringent lotions may be used to hasten the process. A young patient covered by numerous sores may be kept immersed in a bath with a swim-collar round his neck. The water requires frequent changing, and permanganate of potash or boric acid may be added.

Extensive bed-sores are met with in exhausted patients. If not actively treated, the ulceration may spread to the spinal meninges and set up fatal meningitis. It may be complicated by sloughing of the bladder, septic pneumonia, etc.

CHAPTER X.

SURGICAL TUBERCULOSIS.

Definition.—Tuberculosis has been defined to be (Watson Cheyne) "an infective disease due to the growth in the tissues of a parasitic micro-organism, the tubercle bacillus." (*Vide* Chap. I.) Its histological characteristic is a tissue of new-formation, occurring in either a nodular formation (the classic tubercle) or as a diffuse infiltration (Nélaton), in which are found the essential "epithelioid cells," combined or not with "giant cells." This new tissue presents a marked tendency to undergo a special form of degeneration—anemic and coagulation- or toxin-necrosis—termed caseation, and to excite a chronic form of inflammation around it.

Frequency.—In former times the subject of tuberculosis was commonly relegated to the physician; but, since the establishment of the identity of scrofula and tuberculosis, the ravages of the tubercle bacillus furnish to the modern surgeon at least one-quarter of his work.

Incidence.—Almost every organ of the body may be invaded by tubercle; but in some its frequency is great, while in others it occurs but rarely. Amongst the former may be mentioned the lymph-glands, the brain and its envelopes, the lungs, pleuræ, and peritoneum, the bones, joints, and testicles; and amongst the latter the muscles, ovaries, pancreas, and the thyroid gland. While the Bacillus tuberculosis constitutes the seed of the disease, a special "abnormal vulnerability" (Virchow) of the lymphatic tissue affords a favorable soil for its fruition. This is the body state described by the older writers as the strumous or scrofulous diathesis, a state which may be either inherited or acquired. This same state likewise increases the susceptibility of the system to other infections than the tuberculous, such as the syphilitic and the so-called zymotic. Different physical types have been ingeniously described as associated with this condition. They are two—the fair and the dark; and usually each of these presents two varieties—the fine or sanguine, and the coarse or phlegmatic. In the late Sir John Erichsen's text-book they are thus briefly and well described:

"The most common is that which occurs in persons with fair, soft, and transparent skins, having blue eyes with large pupils, light hair, tapering fingers, and fine white teeth; whose beauty, indeed, is often great, especially in early life, being dependent rather on roundness of outline than grace of form, and whose growth is rapid and precocious. In these individuals the affections are strong and the procreative power considerable; the mental activity is also great, and is usually characterized by much delicacy and softness of feeling, and vivacity of intellect. Indeed, it would appear that in such persons as these, the nutritive, the procreative, and the mental powers are rapidly and energetically developed in early life, but become proportionately early exhausted. *Cito maturus, cito putridus.*

"In another variety of the fair scrofulous temperament we find a coarse skin, short and rounded features, light gray eyes, crisp and curly sandy hair, and short and somewhat ungainly stature, and club fingers; but not uncommonly, as in the former variety, great and

early mental activity, and occasionally much muscular strength. In the dark form of scrofulous temperament we usually find a more heavy, sullen, and forbidding appearance; a dark, coarse, sallow or grayish-looking skin; short, thick, and harsh curly hair; a small stature, but often a powerful and strong-limbed frame; with a certain degree of torpor or languor of the mental faculties, though the powers of the intellect are remarkably developed. The other dark strumous temperament is characterized by clear, dark eyes, fine hair, sallow skin, and by a mental and physical organization that closely resembles the first-described variety of the fair strumous diathesis."

Frederick Treves regards the members of the sanguine type as those who have inherited the condition; the phlegmatic as having acquired it from the neglect of hygiene in their environment.

Age.—All periods of life are subject to tuberculosis, but the incidence of the surgical aspect of the affection is largely in childhood, the strumous glands and bone and joint affections occurring most frequently, though by no means exclusively in this period. The other extreme of life also manifests a liability to the affection, and "senile tuberculosis" and "senile scrofula," which are now interchangeable terms, are met with from time to time. The affection may have persisted or remained latent from early life, or may have begun *de novo.* The form most frequently assumed is bone or tendon disease (frequently about the wrist, when the well-known pulmonary association is still manifest); but cervical glandular enlargements and other localizations occur.

Histology of Tubercle.—The term tubercle, meaning a nodule, or little node, has in former times been applied to three different stages of the one inflammatory process, and thus three different forms have been described. The crude tubercle was the name applied by Laennec to the gross, macroscopic node of *yellow* color which resulted from the caseation of many coalesced gray nodules; while each gray nodule visible to the naked eye, and having approximately the appearance of a millet seed (milium) while newly formed, and not having undergone fatty disintegration and caseous degeneration, was termed a gray, or *miliary,* tubercle. The microscope soon revealed the fact that each such miliary tubercle was composed of an aggregation of minute, invisible, gray, translucent masses of a similar character, for the designation of which the term *submiliary* tubercle was coined; and for which the histological name tubercle should be reserved to-day.

The tubercle is a histological entity or neoplasm (infective granuloma) of inflammatory origin, resulting from irritation of the invaded tissue cells by the Bacillus tuberculosis or its toxins. Virchow originally taught that its starting point was always in the connective tissue or other mesoblastic structure; but experiment upon animals has shown that "the cells which are nearest the essential microbic cause, irrespective of their embryological origin, their histological structure, or their physiological function" (Senn), are the seat of the inflammatory proliferation. Under the microscope typical tubercles can be demonstrated to consist of three or, perhaps, four constituent elements—leukocytes, epithelioid cells, giant cells, and a reticulum. The reticulum of tubercle, first described by Wagner and Schüppel, is now regarded by most authorities as simply the pre-existing connective tissue, invaded and pushed aside by the new cells, and when furnished with blood-vessels it is invariably so. But in some cases the reticulum

seems to be formed, at least to a large extent, by the processes of the epithelioid cells, or, as Watson Cheyne claims, may be simply diffraction appearances due to defective illumination of the specimens.

As the cell-growth is most active at the center of the mass, and a certain pressure is thus exerted from within outward, there is seen at the periphery a thickening of this network, amounting at times almost to the formation of a capsule (Warren), which appearance is at other times due to the endothelial growth occurring within the vessel whose wall furnishes the seeming fibrous capsule. The reticular fibers are oftentimes well marked. They appear to radiate from the margin of the central giant cell or cells, and to assume a concentric arrangement at the periphery of the granule. The meshes of the reticulum are occupied by some giant cells, epithelioid cells, and lymphoid corpuscles. The whole is called a "giant-cell system."

The giant cells of tubercle (*macrocytes* of Klebs) differ in nowise from those found elsewhere, as in granulation-tissue, gummata, sarcomata, the placenta, inflamed serous membranes, actinomycosis, and bone-marrow (the myeloplaques of Robin). They are, probably, simply overgrown and plethoric cells which, by virtue of their ameboid movement, have succeeded in taking up more than their share of the surrounding pabulum in the shape of fragmented leukocytes. They present one peculiarity, however, in the arrangement of their nuclei, which tend to take up a position in the periphery of the cell with their long axes radiating from the center; sometimes they are "huddled together in a semilunar cluster at one end" (Treves), still preserving, for the most part, however, their radiating axial arrangement. Vacuoles or necrotic foci are of frequent occurrence in giant cells. Apparent vacuoles may result from faintly stained or only marginally stained nuclei. The bacilli of tuberculosis, abundant enough in experimental tuberculosis, but much less numerous in human pathology, are found within the giant cell, but manifest a preference for its peripheral part, more marked as central degeneration progresses. This central degeneration, called *caseation*, is a marked characteristic of the giant cell, and consists in an anemic or toxic coagulation-necrosis of the protoplasm, which has a strong tendency to spread throughout the cell, and from one giant-cell system to another, and thus to give rise to coarse cheesy masses so characteristic of the tuberculous process.

In the absence of caseation, there are a disappearance of the bacilli, a fibrosis of the cellular elements, and conversion of the tuberculous mass into cicatricial tissue. The origin and significance of the giant cells have been matters of much dispute. They have been traced by different observers to epithelial cells, to endothelial cells, to connective-tissue cells, and to leukocytes; while others have denied their cellular character and regarded them as lymph-spaces filled with coagulum, with the swollen endothelium of their walls posing as nuclei. The view of Baumgarten is generally held, that the giant cells result from the overgrowth of the cell with multiplication of its nuclei without a corresponding division of its substance—possibly the result of the irritation of the bacilli in its interior. The fusion of several epithelioid cells has been invoked to explain the giant cell. Welcker, repeating the experiments of Metschnikoff, found "no evidence of multiple karyo-

kinesis in the epithelioid cells, and questions this mode of formation for giant cells. He regards direct nuclear division as the most frequent mode of formation, but does not exclude fusion" (Hektoen). So far as the significance of the giant cell is concerned, Baumgarten and Weigert regarded it as a stage in the process of destruction, necrobiotic in its very conception; while the school of Metschnikoff, of which Ludwig Hektoen is the latest exponent, have marshalled a great deal of evidence to prove that it is a "living, active, and defensive (mesodermal) element," the function of which is to counteract and destroy bacilli, and ultimately to play an important part in the development of the victorious cicatricial tissue. The giant cell is not an essential or invariable accompaniment of tubercle. In the process of caseation it is one of the last structures to disappear.

The epithelioid cells of tubercle, the platycytes of Klebs, are intermediate in size, and mostly in position between the giant cells and the leukocytes, and are two or three times the size of the white blood-cell. They are finely granular, somewhat flattened cells, with a large oval or elongated nucleus, bearing some resemblance to an endothelial cell and to certain epithelial cells, which circumstance led Rindfleisch to designate them "epithelioid." They commonly have only one faintly stained nucleus, but two or more may be present. They constitute the bulk of all recent tuberculous nodules, or tracts of tuberculous infiltration, and being invariably present, and usually holding certain definite relations to the tubercle bacilli, may be properly regarded as the essential histological element of tubercle.

Cheyne asserts that the quickest way to find tubercle in any given tissue is to search with a low power for tracts of epithelioid cells, and to look amongst these for the bacilli, which are easily to be found in or among them—in his opinion, commonly within them—while the inflammatory cells beyond are void of organisms. As in the giant cells, the bacilli, when present, affect the neighborhood of the nucleus of the epithelioid cells. In further support of the view that the epithelioid cell is the essential element of tubercle, Baumgarten has found in tuberculous tissue nuclear division only in the epithelioid cells. The sources of these cells are various, and they may be derived from the epithelium, from the endothelium of blood- and lymph-channels, and from the tissue and plasma-cells of the invaded structures.

Caseation often affects the epithelioid cells, but it does not usually begin in them, commencing more often in the intercellular substance of the giant cell. In the process of healing they atrophy and are converted into fibrous tissue.

The leukocytes, or **lymphoid corpuscles,** are the remaining element of the tuberculous nodule to be considered, and their presence is a convincing proof of the inflammatory character of the process. They are invariably present, and abundant in proportion to the acuteness of the process, are scattered among the other cellular elements, and congregate at the periphery of the nodule. Bacilli are not found among them, except in sputum (J. J. Mackenzie), and they undergo no transformation except degeneration. They constitute, however, a cellular barrier around the tubercle, and are occasionally reinforced by a fibrous wall, particularly, as has been said, if the process has occurred within a vessel. Cohnheim and Ziegler maintain that the leukocytes form the bulk of the tubercle nodule; the epithelioid and giant cells a minor part.

It will thus be seen that the tubercle is simply a circumscribed, inflammatory nodule, produced from proliferation of fixed tissue-cells, stimulated by the presence of the Bacillus tuberculosis and its toxins, and surrounded by the usual inflammatory exudate of leukocytes. Owing, however, to its infective character, it tends to spread by constant multiplication of its foci; and thus not only is it locally infective, but its virus may be disseminated from every focus to distant parts by the lymph- and blood-currents. It may also be conveyed from man to animals, from animals to man, and from man to man. This tendency to the formation of fresh tubercles is one of the chief and distinctive characteristics of tuberculosis; and each tubercle (nodulation or infiltration) is in its time destined to retrogressive change.

Three chief forms of degeneration are described: (α) Simple atrophy and disappearance of the tubercle; (β) rapid caseation and breaking down, often leading to what is termed suppuration (chemical and cold); and (γ) slower degenerative changes, generally ending in some degree of calcification, the deposit of lime salts following upon the process of caseation.

Channels by which the Virus Enters the System.—That the Bacillus tuberculosis may pass from the mother to the fetus *in utero* has been indisputably established, by direct observation in both animals and man more than once, since Baumgarten asserted its possibility; but that it does so with infinite rarity the accumulated evidence also establishes. This mode of propagation may therefore be practically disregarded. What is undoubtedly acquired by heredity, however, is a peculiar susceptibility of the tissues of the body (fluid and solid) to the tuberculous irritant, a condition which affords a favorable nidus for the development of the germ. The route by which the tubercle-germ enters the system most frequently is, probably, the respiratory passage, and, next in frequency, with a common avenue of approach, is the digestive tract. In the former case, dust infected with dried sputum is the likely vehicle of the contagium; and in the latter, tuberculized articles of food, such as meat, milk, and water; and the mucous membrane of the nose may be infected by a soiled handkerchief or towel. Catarrhal and other subacute inflammatory states of these passages facilitate the ingress of the germ. Abrasions and inflammatory lesions of the skin afford an avenue of access through this protective integument; and the mucous membranes of the genito-urinary and alimentary tracts may be infected by accidental contact with germ-laden substances, or secretions, or by unsterilized instruments in the hands of the surgeon, accoucheur, or dentist. Piercing the ears, tattooing of the skin, wounds of the fingers by contagium-bearing china, the rite of circumcision, and various minor lesions of the integument have all afforded examples of infection thus conveyed; and Laennec himself succumbed to phthisis in later years, induced by an accidental wound of the finger incurred in the examination of a body dead of spinal tuberculosis.

The general treatment of tuberculosis must be based upon common sense and what we know of the life history of the germ and nature's mode of dealing with it. Since it is impossible always to control the dissemination of the seed, much attention must be directed to rendering the soil unsuitable for its fructification. This, it is hardly

necessary to say, can be best effected by general and personal hygiene, and living as nearly continuously as possible in the open air, without incurring exposure to too extreme or sudden vicissitudes of temperature. In this respect the oblivious third of life spent in sleep demands at least equal care and supervision with the waking hours; and the securing of an uninterrupted and unlimited supply of pure, fresh air, unattended with draughts, throughout the night, should be for and on behalf of the tuberculous patient the object of earnest and constant solicitude. The maximum amount of sunlight, the virtue of which, locally applied, should not be forgotten, should be sedulously sought. To complete the "trinity of healing graces," an abundant supply of wholesome, assimilable food may well be added.

Dryness and porosity of the soil, remoteness from the bed of streams and luxurious vegetation, propinquity to the sea or the mountain top, are conditions of environment much to be desired.

Amongst drugs which, under varying conditions, prove of service may be mentioned iron, manganese, quinin and strychnin, iodin, chlorin, and phosphorus, with their potash, soda and lime salts, creosote and guaiacol, cod-liver oil and ichthyol, protonuclein and methylene blue, and the whole host of antiseptics; but any or all of these, in the absence of the first-named trinity—free air, free sunshine, free nutrition—are broken reeds indeed.

Surgically, all causes of local irritation and disease—carious teeth, chronically enlarged tonsils, cutaneous eruptions, parasites, catarrhs, ulcerations, and what not—should be carefully sought for and speedily removed, as giving rise to conditions markedly favoring the localization and the fructification of the germs; while, on the other hand, local fixity and rest (wherever the affected part may be), unimpeded circulation, asepticity, and whatever other conditions may be favorable to cicatrization must be promptly enforced as powerfully tending to assist the tissues in combating the invaders of their peace and sanctity. Furthermore, bearing in mind that the natural mode of cure is by fibrosis when possible and by ulceration when necessary, it is clear that so soon as it becomes apparent that natural efforts at cicatrization, favored by such means of art as tend to sclerogenesis, are likely to prove unequal to the task, eradication of the local lesion at the surgeon's hands is urgently demanded. This may be effected by fire and sword. When possible, complete ablation with full antiseptic care and primary union is much to be preferred. But where the local conditions render this impossible or inadmissible, free excision, with removal of undermined and infected skin, and thorough scraping of the affected focus, may be hopefully resorted to. This should be followed by swabbing with chlorid-of-zinc solution (40 grains—2.6 gm.—to the ounce), or with pure carbolic acid, penetrating all recesses, nooks, and crannies, and afterward by packing with sterilized iodoform and iodoform gauze, with a large antiseptic dressing, and fixation by splintage, where available. Under these circumstances, recovery is much slower, and may be interrupted by recrudescences and relapses, demanding a repetition of the treatment.

TUBERCULOSIS OF SKIN AND MUCOUS MEMBRANE.

General.—(*a*) Lupus; (*β*) tuberculosis vera cutis; (*γ*) scrofuloderma.

Local.—These are essentially localized—that is, unassociated with general tuberculosis; and Zeisler describes four varieties: (*a*) Verruca necrogenica (anatomical tubercle); (*b*) tuberculosis verrucosa cutis; (*c*) tuberculosis papillomatosa cutis; (*d*) tuberculous ulcerations of skin, of tongue, of pharynx and larynx, of different parts of the alimentary tract, including fistula in ano.

Lupus Vulgaris.—Senn makes the statement that "all forms of primary tuberculosis of the skin are the result of direct inoculation with tubercle bacilli"; and if we could accept this dictum implicitly and without reserve, then we should agree with what he says about the description given of the different forms of tuberculosis of the skin—viz.: "It is time that these immaterial and unimportant distinctions should be set aside, and these different affections should be included under one head, as primary tuberculosis of the skin, since all of them present the same histological structure, and all are caused by direct inoculation with tubercle bacilli." But "Jonathan Hutchinson does not accept the inoculation of the tubercle bacillus *from without* as an ordinary cause of lupus. It seems to him far from probable that the parasite exists during long periods in a state of latency, from which any local injury may arouse it into a state of activity." All, however, are agreed upon the causative agency of the Bacillus tuberculosis. This was foreshadowed clinically for a long time before the demonstration was forthcoming. Thus Hebra and Fuchs agreed with the leading French and English authors who taught that lupus was one of the manifestations of scrofula, and that anatomically it was composed of granulation-tissue.

Virchow, Rindfleisch, Hueter, and many others very nearly approached the truth, but Friedländer was the first to assert positively its tuberculous character and to demonstrate the presence of miliary tubercle in it. The crucial test of bacteriological experiment has been decisive.

The artificial tuberculosis produced in animals by implantation of lupoid tissue has been found by numerous investigators to contain the Bacillus tuberculosis.

"The characteristic and primary feature of lupus is a *reddish-brown*, or *pinkish*, or *yellowish* nodule, becoming paler but not disappearing on pressure, of soft consistency when pressed upon by a blunt instrument, situated beneath the epidermal layers of the corium" (Bowen). This nodule, or lupoma, varies in size, pursues a slow and chronic course, and in its evolution or involution presents a variety of appearances characterizing the different forms of lupus.

Leloir affirms that at the seat of the disease tactile sensibility is diminished and the local temperature raised. If the nodule is not raised above the surface and is hardly perceptible to the touch, it is termed *lupus maculosus*. The macular form may be preserved throughout, or the nodule may grow into elevations perceptible to the touch, giving rise to what is termed *lupus élevé*. When many such nodules have coalesced into a mass, the swelling has been termed *lupus tumidus*. If these patches do not ulcerate, a process of involution and contraction occurs, the nodule shrinking up, and the overlying epidermis consequently becomes thicker and scaly. *Lupus exfoliativus* is thus produced, tending to end in a cicatricial contraction.

The original lupus nodule is apt to be attended by a circle of satellites, and, the central portions undergoing absorption and cicatrization.

while the periphery is breaking down and spreading irregularly, a very common, important, and intractable clinical variety arises, which is of long duration, highly deforming, resistant to treatment, and called *lupus serpiginosus*.

When, on the other hand, the process of softening and breaking down from necrobiosis occurs, the variety termed *lupus exulcerans* or *lupus exedens* is developed. The so-called ulcers thus arising are oftentimes covered with crusts composed of the cheesy material of the degenerated tuberculous tissue, and oftentimes the products of secondary septic infection, and a condition arises sometimes closely resembling eczema impetiginosum. When the crusts are removed, the lupus ulcer is seen to present soft, reddish borders, and a red or grayish, granular base, painless and insensitive, and of soft consistency. Sometimes an exuberant granular growth occurs and large fungoid masses are developed, giving rise to *lupus papillaris verrucosus*, the favorite seat of which is the nose. *Lupus vorax* and *lupus phagedénique* are classifications descriptive of the extent and depth of the ulcer. Lupus is impartially destructive in its progress, and all tissues are in turn destroyed—cartilage, particularly, falling an easy prey.

Localities.—The face is the favorite site for all forms, the nose especially; and of this organ, particularly the alæ, and sometimes the mucous membrane, where it oftentimes exists as an obstinate crusting. The cartilaginous septum is attacked with avidity, but the bone not so; whence results the appearance described as the "lopped-off" nose of lupus, as distinguished from the "sunken-in" nose of syphilis. The cheeks, lips, and ears are frequently attacked, the external auditory canal and membrana tympani occasionally. Lupus of the forehead and scalp is rarely primary, though Hebra, Kaposi, and Leloir have described one case each. One writer has aptly said that the disease may spread anywhere and everywhere until naught remains but the cicatrix stretched tightly over the bone, studded here and there with nodules of new disease.

Lupus of the extremities is not uncommon, and is met with next in frequency to the face. It is most intense from the elbows and hands downward, frequently serpiginous in outline, and begins over the points of the articulations, rarely upon the palms or soles. Great deformity from cicatricial contractions, fistulæ, caries, necrosis, and elephantiasis from obstructed circulation, recurrent lymphangitis, and dermatitis may result. Lupus of the genitalia is very rare. Hebra met with it once upon the penis, and Taylor has seen it on the vulva.

Lupus of mucous membranes is, perhaps, rare as a primary affection, but secondarily it occurs very frequently. Yet primary lupus of the mucous membrane of the nose is not infrequent, and is often mistaken for eczema narium. Indeed, Neisser believes that the most frequent extension is from the nose to the face. The special characteristics are not so marked in the mucous membranes, owing to the thin epithelial covering not offering much resistance to the infiltration, and to the constant maceration by the secretions. According to Chiari and Riehl, the lupus nodule of the skin is replaced in the mucous membranes by papillary excrescences, and they assert that the brown-red impalpable nodules in the cicatrix are pathognomonic. Lupus of the conjunctival

mucous membrane is rare as a primary affection, and attacks the lower lid first. Lupus of the mouth and pharynx generally coexists with lupus of the skin. It appears upon the gums, and Leloir once found it on the vault. In the tongue it is rare. In the larynx Leloir met with it in 2 per cent. of his cases; and Chiari and Riehl's statistics showed that the epiglottis was almost always affected (35 out of 38 cases).

Leloir has described a *lupus colloïde* and *myxomateux* in which the degenerations characterized by these names have occurred.

Epithelioma or epitheliomatous change not infrequently complicates lupus.

Diagnosis.—The diagnostic features of lupus may be said to be the youth of the patient, the "apple-jelly" appearance of the nodules, the cicatrization of the center while spreading at the margin, and the tendency to relapse.

The Prognosis.—Owing mainly to the difficulty of removing the growth in its favorite locality—the face—beyond the area of local infectivity, the ultimate prognosis is always doubtful. The prospect of local improvement under judicious treatment is always good.

Treatment.—The general treatment of lupus is that which is proper for all forms of tuberculosis. In the local treatment it would naturally be expected, in view of the character of the affection, that excision would prove the most useful and satisfactory remedy. Practical experience, however, has shown that this is not the case, owing doubtless to the before-mentioned difficulty of cutting wide of the disease in those portions of the body where it most commonly occurs. For this reason relapses in the cicatrix are not uncommon after excision. Linear scarification has been much lauded by Volkmann in Germany, Vidal in France, and Balmanno Squire in England. Curetment with a sharp spoon or curet, being more generally applicable in all situations, has, on the whole, given the most satisfactory results, when freely followed by the application of the cautery or antiseptics and iodoform dressings. Bougard's paste (cocainized) occasionally finds useful application here, and the thermocautery, either along with or following curettage, is a valuable instrument. Caustics of various kinds, but particularly the pointed stick of silver nitrate with which the nodules may be individually penetrated and destroyed, are oftentimes attended with satisfactory destruction of the growth.

Tuberculosis vera cutis is a rare affection, always secondary to tuberculosis of mucous membranes, and called by the French *ulcère des phthisiques*. Chiari was the first to notice this, on the lower lip of a cadaver, and Jarisch *intra vitam*. The location is almost exclusively at the junction of skin and mucous membrane; but Jarisch, Leloir, and Vallas have reported instances elsewhere. The characteristic appearances are simple shallow ulcers with edges made up of small jagged indentations, resulting from the degeneration of miliary tubercles, giving a "gnawed-out" appearance. The floor is not, as a rule, crusted, but is covered with a seropurulent fluid, and with occasional yellowish elevations, representing miliary tubercles, scattered over it. These ulcers, unlike those of lupus, are usually painful, probably owing to the site of occurrence. When occurring on the glans penis they have been shown to be secondary to tuberculosis of the urinary passages, except when inoculated by the Jewish rite of circumcision, of which Lehmann has recorded 10 cases. Similarly in the vulva they are secondary to tuberculosis of the uterus and tubes. The course of these ulcers is variable, depending largely upon the progress of the general affections with which they are associated.

Scrofuloderma is that form of tuberculosis which affects the sub-

cutaneous connective tissue. It may be either primary, or consecutive to softening of lymph-glands, or occur as perilymphangitic nodules.

Verruca necrogenica (anatomical tubercle) is found upon the fingers and the dorsal surfaces of the hands of pathologists, the result of infection. It begins as a simple red nodule, which becomes pustular and soon covered with a scab. Gradually it spreads on the surface, becomes thicker, and is covered with papillary growths, giving a warty appearance. It has a well-defined margin. Here and there on the surface are seen small points of pus, which can be squeezed out from the deeper layers. In some cases the eruption is painful, in others indolent; in all, it may spread through the lymphatics and give rise to fatal visceral tuberculosis (Warren).

Tuberculosis verrucosa cutis was first described in 1886 by Riehl and Paltauf. In this the patches vary from the size of a dime to that of a silver dollar. When fully developed, three concentric zones may be observed, the peripheral one erythematous, the second composed of little pustules or of scales covering pustules, the skin of a reddish-brown color and infiltrated, and the central zone raised 0.1 inch (2–3 mm.) and covered with papillary growths at the center. Between the warty growths are fissures and small abscesses. The growth is very sensitive, of slow progress, lasting from two to fifteen years. The lesion is situated in the superficial layers of the cutis, rarely descending to the level of the sudoriparous glands (Warren).

Tuberculosis Papillomatosa Cutis.—Of this an isolated case has been described by Morrow. It was remarkable for the extent and amount of the warty tubercular growth, which involved the cheeks, the upper lip, the nose, and the eyelids. The hypertrophic condition and the papillary excrescences were noteworthy features; but it is doubtful if it deserve a separate classification.

Tuberculous Nodes; Scrofulous Nodes; Scrofulous Gummata.—Under this head has been described a subcutaneous manifestation of tuberculosis, at first hard and nodular, afterward softening, spreading, and breaking down. Its seat is commonly the subcutaneous connective tissue, but it sometimes starts from the periosteum, and on ulceration exposes bare bone. When occurring over the skull and the patella, perforation of the bone cannot infrequently be made out. The treatment consists in excision where admissible; and where this cannot be done, thorough and vigorous scraping followed by the cautery, chlorid of zinc (40 grains—2.6 gm.—to the ounce), pure carbolic acid, and iodoform.

Lupus erythematosus has been included amongst the skin-manifestations of tuberculosis by some advanced authorities under the leadership of Besnier; but the tuberculous origin of this symmetrical, later-appearing affection has never yet been satisfactorily established, and most dermatologists strenuously deny it on both clinical and pathological grounds.

Treatment of Skin Tuberculosis.—Dry hot air (driven through a red-hot metal tube, after Hollander's method, raising it to a temperature of 300° C.), directed upon the affected area, exercises a remarkable and beneficial caustic influence upon the part. The Röntgen rays, concentrated sunlight, and the electric light have been spoken of favorably, as has also electrolysis. In the way of general treatment, arsenic is the drug of greatest service, combined with various tonics. The cantharidate of soda or potash has been recommended for interstitial

use (Liebreich). Koch's *Tuberculin R*, administered within a reactionary limit of ½° C., has certainly proved of great temporary utility.

Tuberculous ulcerations of local origin, as in wounds by broken spittoons, infection of wounds by sputum-soiled articles, the saliva of the operator in the Jewish rite of circumcision, and so forth, are best treated by excision when applicable; but, when from extent or locality this is out of the question, compresses soaked in mercuric chlorid solution, 1–2 grains (0.065–0.13 gm.) to the ounce (White), or permanganate of potash, ½ per cent. to 2 per cent. (Butte), may be employed, the pain being relieved by the subsequent application of a cocain ointment. Salicylic acid in ointment, or in Unna's plaster-mulls, or made into a paste with creosote and balsam of Peru, finds a useful application in tuberculosis of the skin.

Old sinuses, as in Pott's disease, may be dissected or thoroughly scraped out, swabbed with a 95 per cent. glycerin solution of carbolic acid, sutured, and compressed. Not infrequently primary union occurs.

TUBERCULOUS LYMPHADENITIS.

This is one of the most common manifestations of the tuberculous process, and constitutes a large proportion of the cases of chronic lymphadenitis that come under observation. The glands most likely to be affected are, of the superficial set, the cervical glands, the cubital, and less frequently the axillary (Volkmann). The glands of the lower extremity are much less often affected. As a post-mortem observation it has been stated that in children the order of frequency is the cervical, the mediastinal, the mesenteric, and the retroperitoneal; and it is an astonishing fact that in more than one-half of all the autopsies made upon children, evidences of tuberculous adenitis are to be found. While the frequency of incidence is as above stated, any or all of the glands of the body may be implicated.

The affection may be primary or secondary. When secondary it is generally engrafted upon catarrhal affections of the mucous or cutaneous surfaces, tonsils, carious teeth, cutaneous irritations; and Treves has attributed the great frequency of the implication of the cervical glands to the extensive collections of adenoid tissue found in the adjoining mucous membranes. The bacilli are generally picked up on the mucous or cutaneous surfaces, and so come by the lymph-current to the glands, but they may gain access by the blood-stream. The affection is a common one in childhood and early adult life, but may be met with between seventy and eighty years of age as "senile scrofula."

The **symptoms** are a slow, gradual, painless enlargement of the glands, often coming on insidiously, of variable duration, and frequently proceeding by fits and starts. The glandular swellings are at first discrete and movable, then become confluent, and when peri-adenitis has occurred subsequently adherent. When adhesions have been formed, softening may quickly follow and ulceration be developed. Suppuration or liquefaction takes place slowly. It may become stationary or even retrogressive, cheesy or calcareous. The skin becomes thin, undermined, reddish-purple or blue, and gradually gives way, discharging

cheesy or curdy pus and débris; this condition may continue for months or even years. The discharging surface may be contracted down to the dimensions of a sinus, leading to a caseous or cretaceous focus. It may heal over and practically cease from time to time, or it may ulcerate widely and present a reddish-gray, fungating, and fleshy protruding mass. When healing occurs, the cicatrices are apt to be thin, blue and weak, adherent, and traversed by hypertrophic bands, forming irregular, puckered, and hypertrophic scars. Occasionally, however, the scars are of surprising fineness and suppleness.

So far as the **pathological anatomy** is concerned, we find the ordinary phenomena of a simple inflammation plus tuberculous foci (gray or yellow), followed by caseation, liquefaction, or cretification. Bacilli are absent in the later stages, but the tissues are still infective, probably owing to the presence of spores.

The **diagnosis** must be made from simple adenitis, from lymphadenoma and lymphosarcoma.

The **treatment** resolves itself into general and local. The general is that which is appropriate for other tuberculous affections. The local involves the treatment of the gland, the sinuses, and the abscesses. While the glands are still small and few in number, surgical intervention may not be required. Painting the surface with iodoform, ichthyol, and belladonna, and securing fixity for the part, together with the constitutional treatment, may be all that is required. If, however, they manifest a tendency to enlarge, to run together, and to soften, they should be promptly removed. In their removal the attempt should always be made to extirpate the gland with its containing capsule, and in view of the importance of the structures to which they are not infrequently adherent, after the gland is reached, blunt dissection is for the most part appropriate. If the capsule be accidentally or of necessity opened, the contents should be removed, and the walls quickly scraped with a sharp curet, the cavity swabbed out with chlorid of zinc (40 grains—2.6 gm.—to the ounce) or a 95 per cent. solution of carbolic acid in glycerin, and subsequently packed with iodoform gauze for three or four days. At the end of this time the gauze should be removed and the opposite surfaces brought together and compressed, under which circumstances primary union will not infrequently occur if uniform pressure and absolute immobility be maintained.

The sinuses, when suitably located, are also best dealt with by complete excision, as will not infrequently happen in cases of fistula in ano. If they cannot be excised, however, they should be thoroughly curetted, and when occurring in the subcutaneous tissue the little bunch of exuberant granulations, which marks the entrance to the subjacent tuberculous glandular focus, should always be sought for and diligently followed up. After a free use of the sharp curet, the sinuses should be treated precisely as before mentioned with regard to the glands whose capsule has been opened.

The treatment of the abscesses is conducted upon the same principle, and often although very extensive, as in cases of Pott's disease of the spine, or the so-called psoas abscess, several well-placed incisions will give access to the whole cavity, allowing of a thorough curetment of the granulation-tissue, subsequent disinfection, and dress-

ing, as in the case of the sinuses. Occasionally cases will be met with in which the iodoform packing may be omitted and primary union sought at once by judicious compression and fixation.

For inducing sclerogenesis about tuberculous foci Lannelongue highly recommended the injection of weak solutions of chlorid of zinc into and around the focus. Liebreich has highly lauded the virtues of the cantharidate of soda and potash as being capable of stimulating the vital resistance of the tissues.

Tuberculosis mammæ is a rare disease, and the literature of the subject is very scant. Roux made a collection of 34 cases, of which 2 were males. In 2 cases both breasts were affected; the age varied from sixteen to fifty-two years; and in 24 of the cases the tuberculosis of the breast was secondary to its occurrence elsewhere. As showing the importance of the breast as the predisposing cause, Mandry's collection of 40 cases gave only 1 in the male breast; most were developed shortly after confinement, the ages varying from seventeen to fifty-two years.

We owe the first scientific study of the subject to Dubar, who published his work in 1881, and who was followed by Le Dentu and by Olnacker in 1883. Roswell Park of Buffalo was the first to treat of the subject in English, in 1887. Since then Orthmann, Hering, Mandry, Roux, Campenon, Lane, Shattuck, and others have made contributions on the subject. A general summary was published by Powers in the *Annals of Surgery* in 1894.

During lactation it is a double source of danger, being liable to infect the mother and the child with miliary tuberculosis.

It usually commences around an acinus of the gland or even within one. The disease begins insidiously. One or more swellings of irregular shape appear, increase pretty rapidly, tend to soften and break down in the center, and form a chronic abscess, which, if left alone, eventuates in fistulæ or sinuses which have no tendency to heal, and will present the usual undermined appearance of a tuberculous sinus.

As before mentioned, the periods of functional activity are most prone to the affection, it occurring during puberty, pregnancy, and the puerperium.

Cold abscesses and chronic fistulæ are the forms generally assumed by tuberculosis of the breast and axilla when they come under notice. Three forms have been described: (α) The single diffuse swelling; (β) multiple fluctuant areas; and (γ) one or more hard nodules in different stages of caseation.

Axillary glands may be involved with or without the formation of abscess, or they may be entirely unaffected. Disseminated tubercles may be found in the tissues around the breast. The disease tends to spread by the lymph-paths.

The *diagnosis* is best made by bacteriological examination, otherwise it may remain uncertain, even when associated with tubercle elsewhere. The upper and outer quadrant of the gland is that usually attacked; and the onset is sometimes secondary to tuberculosis of the axillary glands.

Symptoms of cold submammary abscess may be met with secondary to tuberculosis of the ribs, sternum, or pleura, or to empyema. In primary tuberculosis of the mamma, infection may have taken place along the milk-ducts or by way of an open wound in the breast or nipple.

Spontaneous healing has been observed where the foci were small and few. Encapsulation and calcification may exceptionally occur; but the general tendency is to persist indefinitely and to spread—a constant drain upon the vital powers and a continual menace to the general health.

The *treatment* is the same as for carcinoma, by early and complete ablation, together with the lymph-glands, if any be found to be involved. If the patient be unwilling to sacrifice the breast, the treatment already laid down for sinuses and abscesses will be appropriate and sometimes successful.

TUBERCULOSIS OF THE SEROUS MEMBRANES.

Serous membranes may be affected by tuberculosis either primarily or secondarily. In the latter case the focus may be found in a subjacent viscus, in neighboring connective tissue, or in adjacent lymph-gland or bone. Thus we may have tuberculous meningitis from middle-ear or mastoid disease, pleuritis from pulmonary or rib tuberculosis, and peritonitis from tuberculosis of the mesenteric glands, intestines, or Fallopian tubes.

The rôle of the surgeon in these cases is generally that of an operator, and the diagnosis, causation, and associations or complications are commonly determined before he is called in. His part is therefore limited to the local operative treatment.

Tuberculous Meningitis.—The evidence so far accumulated does not warrant a belief that any material amelioration is to be expected from surgical intervention in this condition. It goes to show, however, that it may contribute somewhat to euthanasia by diminution or arrest of convulsions through the removal of tension by puncture or aspiration of intracranial or spinal fluid. The withdrawal and examination of fluid has, however, on numerous occasions proved helpful in diagnosis. Thus D'Astros is of opinion that "in ventricular hydrocephalus the small proportion of albumin and the abundance of sodium chlorid found in the exudate furnish a ready means of distinguishing the cerebrospinal fluid from that found in the extraventricular effusion." Whilst he expects nothing from surgical procedure in the former, he hopes to find much practical utility in the latter.

The older methods of relieving intracranial tension by the use of the trephine and puncture have in a measure been superseded by the adoption of the suggestion made by Wynter, and carried out by Quincke, of withdrawing the fluid by puncture in the second, third, or fourth intervertebral space of the lumbar spine. Fürbringer has had quite an extensive experience with the method, and in 37 cases of tuberculous meningitis, he succeeded in demonstrating the tubercle bacillus in 30, or 80 per cent.

The puncture should be made, with the patient sitting up or bent forward, on the plane of the junction of the superior and middle thirds of the spinous process, about two fingers' breadth from the median line. After passing through the skin the needle should be directed a little upward and inward. "With new-born infants the needle should penetrate 1 cm. ($\frac{3}{8}$ inch), and with older children the depth should be increased, approaching 7 cm. ($2\frac{3}{4}$ inches), which is the depth necessary

in the robust adult." Heubner prefers lumbar puncture to tapping of the ventricles in chronic hydrocephalus. The method, however, has not been uniformly void of unpleasant symptoms. It goes without saying that the strictest antiseptic precautions must be rigidly observed in its practise.

In **tuberculous pleurisy** and **empyema,** on the other hand, surgery finds a field for frequent useful and beneficent employment, as well as in the non-tuberculous varieties, though it is with the former alone that the present chapter is concerned. According to Netter's tables, empyema in children is of tuberculous origin in only 25 per cent. of the cases, the other 75 per cent. being due to the Bacillus pneumoniæ (53.6 per cent. to 60 per cent.), the Staphylococcus pyogenes, or Streptococcus, Eberth's bacillus, and the Bacillus coli communis; while the statistics of Netter and of Eichhorst placed the frequency of tuberculous pleurisies at 65.2 to 68.5 per cent. in adults.

Three methods of **treatment** are available—simple aspiration, drainage, and rib-resection (thoracoplasty, or Estländer's operation). In every case operation should be preceded by the withdrawal of fluid by the hypodermic syringe or special exploring trocar for verification of the diagnosis, care being taken that, after disinfection of the syringe and needle, any coagulating antiseptic shall be removed in sterilized water before the puncture is made.

Simple Aspiration (Thoracentesis, Paracentesis thoracis).—The sites of election for the puncture are the sixth or seventh space, just in front of the posterior fold of the axilla; the eighth or ninth space, external to the angle of the scapula; and the fifth space, just external to the costal cartilage (as recommended by John Marshall), or where bulging is most prominent or dulness greatest.

The means employed are the ether spray or ethyl chlorid as a local anesthetic, cocain being generally inadvisable on account of its depressing influence; a Dieulafoy, Potain, or other aspirator, or a trocar and cannula, with tube and basin of antiseptic solution for siphonage. The puncture should be made valvular by a preliminary drawing-up of the skin. The removal of the fluid should be effected slowly to allow of gradual expansion of the lung, and much distress, or cough, or blood is an indication for cessation. After the fluid is withdrawn, the puncture in the skin should be sealed with a film of cotton soaked in acetanilid and collodion. The fluid should be preserved for chemical and microscopical examination. A purulent effusion may occasionally be permanently cured in the child after one or two aspirations (particularly if due to the pneumococcus), but this is not to be looked for in the adult. The view has been entertained by some that the tuberculous lung is the better for the compression and splintage of the effusion; such persons would, of course, object to aspiration.

Drainage by Puncture, Simple Incision, or Rib-resection (Thoracotomy).—When the fluid in the pleural cavity has been shown by aspiration, by the hypodermic syringe, or otherwise, to contain pus, drainage, except occasionally in the child, should be at once resorted to. If this be not done, nature will attempt to evacuate the abscess-cavity either through the lung or through the third intercostal space a short distance from the sternum. The sites of election for drainage are those

already mentioned in connection with aspiration. Any bulging or "pointing" spot may properly be incised, but if not suitable for drainage should be supplemented by another opening in one of the aforesaid appropriate positions. Too low a point should not be selected, as it may be covered by the diaphragm, which rises after the evacuation. As a general principle, it may be affirmed that the point best suited for long-continued drainage is that calculated to be the last to close, somewhere in the equator of a globular cavity.

In *draining by puncture* all necessary or possible antiseptic precautions, with regard to operator, field of operation, and instruments, having been duly and scrupulously observed, and the site selected, a short incision may be made by a sharp knife through the skin, and a trocar and cannula, as large as the intercostal space will admit, thrust sharply through the muscle-wall and the pleura, the thrust being thus made so as to perforate and not push the serous membrane before the cannula. The upper edge of the lower rib bounding the space should be hugged, so as not to endanger the larger branch of the intercostal artery, which runs under cover of the groove in the lower border of the upper rib.

When the fluid has been evacuated a rubber tube may be passed through the cannula, the latter is then withdrawn, and the former is fixed in position by safety-pin or stitch, or by having its free extremity split, turned over, and fastened on the chest-wall as a flange. Where danger of compression of the rubber tube exists, a metal sheath may be properly employed for the portion which lies between the ribs. The tube should project just within the pleura and no more, since nothing is gained by having a foreign body within the cavity; and if it be desired to irrigate subsequently, a smaller tube may be readily passed through the larger one to the bottom of the sac, if need be. Pulmonary exercises and gymnastics may be employed to facilitate drainage. Both pleural cavities should not be drained at once; or not until some degree of lung-expansion has been obtained. In view of the possibility of syncope, withdrawal of the fluid should be accomplished slowly, recumbency maintained, and stimulants kept within reach. If obstruction of the tube occur, as not infrequently happens from a coagulum of pus, blood, or lymph, it will be convenient to have at hand a hook, or bent wire, wherewith to effect its removal. Failing this, a probe, or director, or stream of antiseptic fluid will dislodge it backward into the cavity again. Oftentimes the width of the intercostal space is insufficient to afford free drainage, and then it becomes necessary to increase the opening by the resection of a portion of one or more ribs. This may be effected in the case of one rib by an incision along the mid-line of the rib down through its periosteum, which should then be separated to the necessary extent by a raspatory or rugine (two of which should be at hand, one for the outer side, and a more curved one for the inner), and a sufficient length of the rib then removed either by a Hey's saw supplemented by bone-forceps, or by a costotome. It is well to secure the intercostal vessels by ligature or otherwise, and to remove the detached periosteum or thickened pleura which interferes with free drainage and frequently reconstructs the bone. If portions of two (or more) ribs are to be removed, the first incision may be made in the intercostal

space, and the ribs dealt with as before; or, as is to be preferred, after Gould's manner, by a vertical incision covering both ribs.

Drainage by Rib-resection.—In some cases, after free drainage of the pleural cavity has been secured and long maintained, it becomes apparent that from failure of lung-expansion and diaphragmatic accommodation, and insuperable rigidity of the costal wall, obliteration of the suppurating space cannot take place, the only remedy then is to break down and remove the bony wall. This practice was first suggested by Warren Stone of New Orleans, but popularized by Estländer, under whose name it goes. The object is to allow the granulating surfaces to fall together, to coalesce, and to cicatrize; and this can be accomplished only by the entire removal of the bony barrier. The extent of the operation will therefore depend on the size of the cavity, and will vary from the exsection of portions of two or three ribs to the removal of nearly the whole of the bony part of all from the second to the seventh inclusive. Above the second it is not well to go, owing to the relations of the subclavian vessels; and below the seventh it is not usually necessary, owing to the adaptability of the diaphragm. For this operation general anesthesia is necessary, and must be conducted with more than ordinary care and circumspection. A practical point of some importance in the operation is to see that the patient is not turned too much upon the sound side, whereby his respiration may be seriously embarrassed, and, if any communication with the bronchus exist, pus might find its way into the opposite bronchial tract. Various incisions may be used to gain access to the bone to be removed. Godlee recommended a large U-shaped incision, with the base upward, allowing a large flap to be turned up and the costal wall well exposed; it is apt to be, however, attended with a great deal of hemorrhage. Jacobson proposed several similar smaller ones. Estländer employed an intercostal incision, through which he removed a rib above and one below, and made as many such incisions as the given case required. The writer has found Pearce Gould's free vertical incision much the best, and through two such—an anterior and a posterior—all the ribs may be removed, from the angles to the cartilages.

Tuberculosis of the peritoneum is met with in three different forms, according to Osler; first, as part and parcel of general miliary tuberculosis; second, a chronic fibrous form, subacute from the outset, attended by little or no exudation, and presenting hard and pigmented nodules; third, a more or less chronic, caseous, and ulcerating form, characterized by a growth of large tuberculous masses, tending to caseate and ulcerate, forming adhesions and communications between adjacent intestinal coils, and accompanied by a serous, seropurulent, or purulent exudation, not infrequently localized or sacculated. It is, of course, of the subacute or chronic variety when the affection comes into the hands of the surgeon, for local treatment cannot be of service in the presence of general, acute, miliary tuberculosis.

The **diagnosis** of tuberculous peritonitis, as of tuberculous affections of the other serous membranes, is made chiefly by exclusion; but the family and personal history may be of importance. If the affection of the membrane be primary—that is to say, if the tubercle bacilli floating in the blood be arrested in the vessels of the membrane

itself and there develop, we may have simply an ascites of slow and insidious development, without rise of temperature or material disturbance of the general health. Under such circumstances we can only arrive at a diagnosis, before exploration, by excluding the usual causes of ascites, such as diseases of the liver, malignant tumors of the peritoneum and viscera, and chronic valvular affections of the heart.

On abdominal section, exit is given to a clear, straw-colored, or sometimes sanguinolent fluid, and the serous surfaces are found to be studded more or less generally with white or yellow tubercles, which may be here and there massed into tumors of considerable size. Sometimes such masses, if very large, can be felt by bimanual palpation *per rectum* or *per vaginam*, and may simulate any conceivable growth. If, as not infrequently happens, the peritoneal fluid be localized by pre-existing or simultaneously developed adhesions, the resemblance to any of the solid or fluid growths peculiar to the locality may be very great. Thus, if confined to the epigastric or hypochondriac regions, we may have very accurate simulations of hydatid cysts, cysts of the pancreas, enlarged gall-bladder, or hydrosalpinx or pyonephrosis. If the lower half of the abdomen alone be involved, suspicions of pregnancy, ovarian tumor, hydrosalpinx and pyosalpinx, or pelvic abscess may arise, and they may be very difficult to settle without a celiotomy or paracentesis. In deciding upon such cases, due weight must be given to the history and course; and the diagnostic value of tuberculin should be tested. For the majority of these conditions, however, celiteomy is indicated and necessary, and the operation for discovery may be readily converted into the means of cure.

When the great omentum is the seat of tuberculous deposit, it is frequently converted into a firm fibrous band or cord, stretching across the abdomen in or just above the region of the umbilicus, and it sometimes bears a strong resemblance to the solid neoplasms of the stomach, pancreas, and retroperitoneal glands.

Tuberculous ulceration of the stomach, small intestine, appendix, colon, or mesenteric glands may give rise to implication of the peritoneum by direct extension, or to peritonitis by perforation, which peritonitis would be of the acute type and demand immediate operation, during the performance of which the ruptures would have to be closed by suture, preferably after the excision of the implicated part, followed, if necessary, by anastomosis.

The Fallopian tube is sometimes the primary focus, giving rise to the extension of the tuberculous process to the peritoneum; and Osler estimates that the tube is involved in from 30 to 40 per cent. of the cases of tuberculous peritonitis, a fact which may afford an explanation of the far greater frequency of its occurrence in the female.

The **radical treatment** of tuberculous peritonitis is as simple as it is for the most part satisfactory, consisting generally of a mere celiotomy, performed with great care, of course, owing to the liability to intestinal and other adhesions. After evacuation of the fluid has been accomplished, in the great majority of cases the abdominal wound should be promptly sutured without flushing or drainage. If a drainage tube be inserted, provision for a late or secondary suture should be made by passing one or more sutures through the site of the drain-

age tube, leaving them to be tied after its removal in twenty-four or forty-eight hours. Some dust the peritoneal surfaces with (sterilized) iodoform, or introduce an emulsion of iodoform in glycerin (sterile), the dose of 40 grains (2.6 gm.) of iodoform being on no account exceeded, since absorption of more than that amount has been known to prove fatal. When large cheesy masses have been met with, it has been proposed to deal with these by ignipuncture (thermocautery), followed by iodoformization. In such cases drainage may be advisable for a short period. In using iodoform gauze as a drain, the writer has found it preferable to leave it *in situ* several days, a procedure which greatly facilitates its removal. Much discussion has arisen as to the *modus medendi* of celiotomy in tuberculous peritonitis. The suggestion of Lauenstein that the admission of atmospheric air or of sunlight with some occult influence, or of air containing germs or toxins inimical to the Bacillus tuberculosis, or the removal of accumulated ptomaïns, are all inadequate to the explanation. It seems not improbable that the stimulus to the lymphatic and blood-circulations, incident and reactionary to the trauma, and the sudden, altered, physical conditions of pressure, so beneficial in simple cases of hydrocele and other like effusions, may exert a similar benign influence in these conditions also.

TUBERCULOSIS OF TENDONS, TENDON-SHEATHS, AND BURSAE.

Tuberculosis of tendon-sheaths is not common, constituting only 1 or 2 per cent. of cases of local tuberculosis. It may be primary or secondary, the secondary form, resulting from extension of the disease from neighboring bones and joints, being much more common. The affection presents itself in three forms. The first is a fungus form, in which the sheath of the tendon is lined by a layer of granulations, $\frac{1}{12}$ to $\frac{1}{4}$ of an inch (2.11–6.35 mm.) in thickness; while a thinner layer covers the tendon itself and sometimes perforates, dissociates, and disintegrates its bundles. This imparts to the palpating finger a sensation of gelatinous semi-fluctuation, and synovial effusion may be entirely wanting. In the second form the fibrinous inflammatory properties of the bacillus insisted upon by König are strongly manifested, and the granulations are converted into large, white, fibrous masses, variously termed "rice bodies" or *corpora oryzoidea*, "melon-seed bodies," "foreign bodies," "loose cartilages," etc. In this form copious synovial effusion is likely to be found, though not invariably, and, in addition to free fluctuation, the rubbing of these bodies against one another is readily perceived. In the third form a simple dropsical effusion into the tendon-sheath, "a hygroma," occurs; and we get an oval, elongated, fluctuating swelling in the direction of the tendon, if the affection be single; or of the tendons, if multiple—the so-called simple and compound ganglia.

The favorite **seats** of this affection are the flexor and the extensor tendons about the wrist-joint, the peroneal tendons, and the tendons about the knee. The possibility of communication with the synovial membrane of the adjacent joints must always be borne in mind in these cases. Occurring in the forearm and palm, an hour-glass swelling is often produced, owing to the constriction of the

annular ligament, beneath which the fluid passes readily from the one swelling to the other.

In the dry form ulceration or necrosis may take place, and the disease spread thus from the tendon-sheaths to the fascial and muscle planes. The tuberculous character of the contents having been destroyed by the fibrosis, is not always demonstrable by the microscope, but proof will generally be afforded by inoculation experiment. The disease is painless, slow, and insidious in its origin and progress, and often exists long before advice is sought, weakness of the joints and fatigue being chiefly complained of.

The **treatment** consists in the evacuation of the fluid and fibrous bodies, followed by scraping off the granulation-layer, vigorous rubbing of the surfaces with iodoform gauze, and the injection of iodoform emulsion, after which suturing, antiseptic dressing, compression, and splintage will usually suffice. Sufficiently free incisions must be made under rigid antisepsis to admit of thorough carrying out of this plan of treatment.

In the dry and ulcerating form a similar line of action may be adopted, but it will generally be necessary to make a clean and thorough dissection of the tendons and sheaths involved, sometimes with autoplasty of the tendons, in doing which the bloodless method of Esmarch will be indispensable, and the relation of the backs of the tendon-sheaths to the synovial sacs of the underlying joints must be constantly borne in mind. The occurrence of sepsis would certainly be fatal to the integrity of the limb, if not to the life. It is surprising what good results are obtained by a complete and successful ablation of the disease tissue, and how perfectly the tendon-sheaths will be restored.

What has been said of tendon-sheaths is also applicable to the bursæ, and the only thing to be said in addition is to enforce the recommendation of Professor John Chiene of a semilunar incision, with reflection of a flap in dissecting out the bursal sac.

TUBERCULOSIS OF MUSCLES AND FASCIAE.

As mentioned in the preceding section, tuberculosis may extend by contiguity from joint and tendon sites to the fascial and muscle planes. It may also occur primarily in these situations; but, so far as muscle is concerned, so rarely as to be a curiosity. Muscle infected with tuberculosis has a grayish look and a hardened feel. In the fascia, on the other hand, primary tuberculosis is by no means rare, and secondary infection very common. The bacillus has a predilection for the fascial planes, and the resulting granulation-tissue spreads along and over them with facility and rapidity, dipping into all their ramifications and dissecting out the contents. When coagulation-necrosis and liquefaction of this tissue occurs, widespread and tortuous "cold abscesses" result.

The principles of treatment are already enunciated; and thoroughness in their application is the key-note of success.

For Tuberculosis of the Bones and Joints see Chapters XIX. and XX.

TUBERCULOSIS OF THE GENITO-URINARY ORGANS.

(So far as the female genito-urinary organs are concerned, this subject will be considered in Chapter XXI., Vol. II.)

Tuberculosis of the penis is an exceedingly rare affection, except, perhaps, for those cases of inoculation in infants in the Hebrew rite of circumcision, of which quite a number have been recorded, mostly by continental writers (Lyndmann, 2 cases; Lehmann, 10 cases; Eve, 2 cases). The wounds or scars become the site, first, of nodules, then of unhealthy spreading ulcers, and in two or three weeks the inguinal glands are affected, some of which suppurate, and some do not.

Tuberculosis urethræ is, according to Kaufmann, always part of a generalized tuberculosis, and occurs secondarily by infection from the bladder or prostate. The prostatic portion is most frequently affected, less often the membranous portion. Vettesen has reported tuberculous ulceration of the meatus in a phthisical patient aged seventeen. An indurated ulcer occupied one side of the meatus and extended into the fossa navicularis; the glands of the groin were enlarged, as were also the epididymis and prostate; and bacilli were found in the ulcer. The autopsy showed, in addition, tuberculosis of the right kidney, bladder, prostate, and the bulbous urethra.

Englisch has described a tuberculous *peri-urethritis* in the deeper portions of the urethra. It may exist either inside or outside the deeper layer of the superficial fascia. "It begins with a discharge of a chronic character from the urethra, followed later by the formation of perineal abscesses and fistulæ." Some of the cases of incurable "watering-pot" perineum are doubtless tuberculous in their nature. Langhans reports a case of polypoid tuberculosis situated in the urethra about one inch from the mouth. The autopsy showed general uro-genital tuberculosis.

Senn mentions a case of **tuberculous ulceration of the dorsum of the penis** which might easily have been mistaken for a chancre. Kraske reports a case in a man aged forty-nine, in whom a *tuberculous ulcer* occurred upon the *dorsum of the glans penis*. There were two irregularly shaped ulcers, the bases having a yellowish, cheesy appearance, with here and there a tendency to the formation of granulations, yielding a thin secretion. The edges were undermined, and the ulcers communicated with one another. The patient was healthy, with no evidence of tuberculosis in the epididymis, testicle, prostate, or elsewhere. The ulcers were of three months' standing when admitted to the Freiburg clinic, they extended deeply into the glands, amputation was resorted to, and microscopical examination showed both typical giant cells and bacilli. The deeper tissues were more affected than the superficial, evidencing a blood-infection rather than a local inoculation. Looten has published a case of Fournier's, a man aged twenty-four with lupus ulcer of the glans penis.

Lupus of the penis is a rare affection, and generally has the disease coexistent elsewhere—on the face, lobes of the ears, or legs. Jacobson has seen only one case, in a young patient with extensive affection of the nose and face. Hutchinson records one on the prepuce in which he circumcised. He explains the rarity of the affection by saying that lupus commonly attacks those parts of the body exposed to thermal changes; and the genitals being kept uniformly warm by the clothing are more exempt.

To distinguish lupus of the penis from epithelioma two points should be borne in mind—lupus begins during boyhood or youth, epithelioma is a disease of old age; lupus advances slowly, leaving cicatrices; epithelioma more rapidly, tending to glandular involvement and ulceration.

Treatment consists in ablation where possible, and in currettage and iodoformization where this is inadmissible.

Tuberculosis of the Prostate.—Korzyurcki asserts that in genito-urinary tuberculosis the prostate is never missed; but whatever may be the primary focus this gland early manifests infection. Nearly all the later authorities concur in this statement, whether they agree with Virchow, Ziegler, Förster, or Steinthal in thinking that tubercu-

losis of the genito-urinary tract always begins in the kidney, or whether they hold with Rokitansky, Birch-Hirschfeld, Bardenhauer, and others, that the initial point is the epididymis or prostate. In view of the situation of the prostate gland, one can readily conceive that primary infection, except by way of the blood-channels, must be exceedingly rare. But its location at the point of junction of the urinary and genital systems with their blood-vascular and lymphatic channels renders it equally liable to secondary infection from both sources.

Tubercle bacilli which have been cultivated in an intestinal gland and found their way into the general peritoneal cavity may readily drop into the rectovesical pouch, and thence invade the prostate and periprostatic tissue, either directly or through the lymph-channels. There is some reason for believing that this may be the explanation of many cases of seeming primary infection of the prostate gland.

The **diagnostic** points may be enumerated as a urethral discharge, consisting of mucus, pus, epithelium, caseous masses, and bacilli—one or all, according to the stage; frequency of micturition; pain on instrumentation; weight, and dragging, and tenderness in the perineum; enlargement; bosselation; softened foci detectable *per rectum;* the presence of tubercle elsewhere; the existence of abscess; the occurrence of non-healing sloughy ulcers and multiple fistulæ. Bryson lays stress upon distinct, hard, pea-sized nodules in the vesicoprostatic veins, and Cabot found corresponding nodules in the lymphatic glands in the same situation. When the nodules are few, small, and peripheral, or in the capsule, they may be void of symptoms; dependence must then be placed upon the signs.

The prostaticovesicular junction is a favorite point for nodulation. Pain in coitus may probably exist, and currant-jelly semen be discharged.

The **treatment** is general and local. In addition to the more ordinary remedies, guaiacol, arsenic, and iodoform have been recommended. Locally, guaiacol may be rubbed into the perineum, suprapubic region, and the epididymis. Ulcers and abscesses must be treated upon general principles. In acute cases Milton affirms that he derived benefit from tartar emetic in $\frac{1}{24}$ grain (0.0027 gm.) doses every three hours. Instrumentation of all kinds should be rigidly avoided, as it serves only to aggravate the symptoms.

Tuberculosis of the vesiculæ seminales is almost never seen, except as secondary to disease in neighboring organs; but that it occasionally occurs there primarily, as Soloweitschik's case shows, cannot be denied.

The symptoms are frequency of micturition, great sexual excitability followed by impotence or sterility, with frequent emissions of blood-stained semen; in the later stages, abscesses and perineal fistulæ. In one case Weichselbaum found a large vein of the pudendal plexus perforated by a tuberculous abscess of the vesicle.

The **diagnosis** must be made by attention to the general history, the local symptoms, the discovery of nodes and dilatations by rectal examination, the presence of bacilli in the semen—which is asserted by some never to occur—and the intolerance of instrumentation.

Treatment is general and local. The local treatment consists in "*stripping*," either by the finger of the surgeon or by Feleki's or

Swinburne's instrument devised for the purpose, which is said to be more effective and less unpleasant. Ablation of the vesicle has been practised in one case by Ullmann, employing Zuckerkandl's semilunar incision through the perineum, with the base downward.

Roux of Paris records two cases in which the testicle and vas were first removed, then a perineal incision was made, the vesicle being pushed into the incision from the rectum and thus removed.

Tuberculosis of the Testis, Epididymis, and Vas Deferens. —*Synonyms.*—Tubercular epididymitis; Tuberculosis testis; Tubercular orchitis; Tubercular sarcocele; Phthisis testis; Strumous or scrofulous disease of the testis; and Scrofulous orchitis. Two varieties are presented:

(α) The general miliary tuberculosis, which is rare.

(β) The form characterized by discrete craggy or nodose deposits.

The most frequent seat is the epididymis, of which the globus major is generally attacked, according to most authorities, but according to

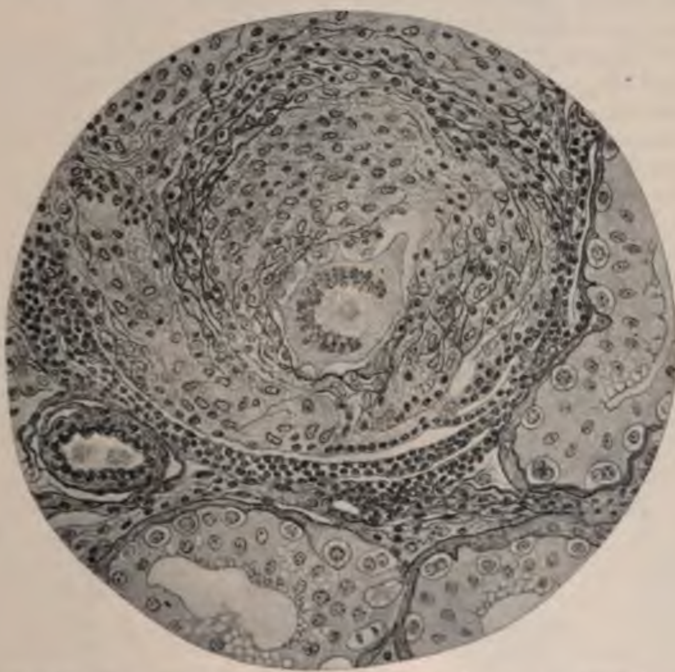


FIG. 53.—Portion of a compound nodule from a tuberculous testis. Seminiferous tubules with spermatogenesis arrested beyond division of the spermatogonia. Interstitial cells with crystalloids. An artery in transection on the left. Lymphoid capsule surrounding the whole nodule. Giant cell with its processes; crescentically arranged nuclei, its necrotic center. Surrounding the giant cell are epithelioid cells and a few lymphoid cells (nuclei represented black). Surrounding the giant cell and epithelioid cells is a reticular capsule infiltrated with lymphoid cells. Outside the reticular capsule are epithelioid cells of other portions of the compound nodule.

Erichsen and H. Eilers, the globus minor. The disease spreads by creeping along the mucous surfaces to the testis or to the vas deferens. The reason assigned for the more frequent early implication of the

epididymis is, according to Salzmann, that the vessels are smaller and more tortuous, and that the spermatic artery breaks up into two branches opposite the epididymis. If the infection takes place from below, *per urethram*, it would follow that the globus minor should be first affected, as in the corresponding affection by the gonococcus. Later on, the disease may spread to the vesiculæ seminales, prostate, bladder, and kidney, or it may give rise to general or pulmonary tuberculosis. Salleron, however, in a series of 51 cases, found other organs infected in only 1, and but 2 deaths in these 51 cases.

So far as age is concerned, the disease usually occurs in early adult life; but it is not seldom met with in infancy and in old age, at which latter period its virulence seems to be much diminished. Giraldés found tubercle of the testicle in an infant at term. Jullien in 16 cases records that 6 were infants under one year. Julius Dreschfeld records a case of congenital tuberculosis of the testicle; and Hutinel and Deschamps think the affection is as common before, as after, puberty, and believe that it frequently commences in the peritoneum.

Three stages have been described:

(α) Of deposit; (β) of caseation, softening, and abscess; (γ) of fistulæ and fungus. The symptoms will vary with the stage. In that of deposit they may be *nil;* but manipulation will reveal the existence of one or several hard, characteristic nodules in the part affected, commonly the epididymis.

Thickening of the vas deferens, particularly at its extremities, is strongly corroborative. In the stage of caseation, the hard nodules will be replaced by fluctuant swellings; and the stage of fistula and fungus then declares itself.

The **diagnosis** from simple or gonorrheal epididymitis is made by the history, the location of the swelling, the absence of pain, and the wooden hardness; from orchitis by similar signs transferred to the testicle; from syphilitic sarcocele, or gumma, by the history, by the implication of the testicle rather than the epididymis, by the special loss of testicular sensation in gumma, by the absence of hydrocele, and by the tendency to the formation of fistulæ. According to Jacobson, hydrocele occurs in about one-third of the cases; the quantity of fluid is small, of unusual density, and contains flocculi and shreds (Réclus).

FIG. 54.—Giant cell from the periphery of a nodule of a tuberculous testis, to show occasional grouping of the nuclei toward the end of the cell. Shows giant-cell processes and reticular fibers passing into the giant cell; also, periphery of the caseating area.

The **prognosis** depends upon associated deposits and the general condition. The local disease may exist for several years without impairment of the general health.

The **treatment** is that of tuberculosis in general. Locally, incision, scraping, and iodoformization, with subsequent dressing with balsam of Peru. Sclerogenesis, by the

injection of weak solutions of chlorid of zinc in the neighborhood of the foci, is recommended by Lannelongue, and the cautery by Verneuil. Reboul of Marseilles advocates injections of naphthol-camphor, and records three successful cases in which 4 or 5 drops (0.24–0.3 c.c.) were injected daily into the thickened tissues for eight or ten days. Castration has been frequently practised successfully. If ulceration has occurred, the tunica vaginalis and infected skin should likewise be

FIG. 55.—Tuberculous testis. Reticular tubercle from periphery of a nodule. Shows reticulation radiating from the giant cell; also fibrils passing into the cell; epithelioid cells, lymphoid cells (nuclei black), and the caseous patch surrounded by a fibrous sheath.

removed, and the cord ligated as high as possible. If both testicles are simultaneously involved, most authorities discountenance castration; but very good results have been obtained by the less radical methods above mentioned.

Tuberculosis of the bladder is rare as a primary affection. When it occurs, the trigonal submucosa is the most likely seat, whether it is brought by the circulating blood or has migrated from the peritoneal cavity. According to statistics, it seems to be three times more common in men than in women. Should infection take place from without, however, the short and direct passage afforded by the female urethra would seem to render women more liable to the disease.

As a secondary affection, tuberculosis may occur in the bladder, either by ascending from the prostate and the epididymis or by descending from the kidney, whence the germ may be brought either in the creeping form along the mucous surfaces, or in suspension in the urinary secretion from the pelvis of the kidney.

The **symptoms** closely resemble those of vesical calculus. It is most frequent in the young, from fifteen to twenty-five years of age; and, according to Bryson, most of the affected will present a history of masturbation upon which they lay great stress, with a family one of tuberculosis or cancer; and a personal one of enuresis up to four or five years of age. Frequency of micturition is the first prominent

symptom, gradually increasing, first by day, and later also by night, as a distention-reflex, with blood at the end of the act. Pain in the mid-penis is frequently complained of, with vesical tenesmus, and occasional sudden stoppage of the stream, with increase of distress. In active cases there may be sloughing of the mucosa with brisk transient hemorrhage.

The **differential diagnosis** from stone may be made by the following points, according to Bryson: 1. The absence of a history of renal calculus. 2. Less effect of exercise upon vesical irritability. 3. Situation of pain in the mid-penis, not passing forward under the glans. 4. Sudden arrest of the stream by voluntary contraction of the compressor urethræ to relieve the pain of passage along the urethra, and not by the sudden blockage of the internal meatus by a stone. 5. The more rapidly increasing nocturnal frequency, and its clear dependence on a distention-reflex. 6. The growing evidence of a contracting bladder.

The guarded, careful use of the cystoscope and bacteriological investigation of the urinary sediments will, of course, afford the most positive and useful information. When infection takes place by way of the urinary current from the pelvis of the kidney, the microscope and bacteriological investigation will afford the earliest information. If the disease creep in by continuity along the ureter, it will likely follow the corresponding trigonal limb, and may not give rise to any symptoms, but should be detected by the cystoscope. This latter form oftentimes closely simulates renal calculus. In all cases of surface-infection the symptoms appear early after invasion; but when infection is from without—*i. e.*, submucously—the occurrence of symptoms is often long delayed, and considerable advance may be made before the patient is aware of anything amiss. The cystoscope, however, is often equal to the detection of these cases also, if attention be directed to the bladder.

In the cases of primary invasion of the middle coat of the bladder by way of the blood-vessels, symptoms are almost entirely wanting, but, when they do appear, they are enumerated by Bryson as consisting of: 1. Weakening of the detrusor-muscle plane, manifested by a slowness to start the stream, a weakness of flow, and difficulty in emptying the bladder. 2. The accumulation of some residual urine in the later stages. 3. A gnawing pain behind the pubes when the bladder is distended, not quickly relieved by micturition. 4. Slight hemorrhages from overdistention. Here there is no frequency, no pus, no bacilli, and seldom blood; and, when occurring in later life, the symptoms may closely mimic prostatic obstruction.

The bladder is sometimes invaded from infected seminal vesicles. Under such circumstances calculus is closely simulated, and this leads to very injurious instrumentation. "Owing to the infiltration-rigidity, distention is interfered with and frequent micturition results, the bladder capacity being limited to 4 or 5 ounces (15–18.5 c.c.). When the bladder is partly empty, relief ensues, followed by recurrence of the suffering as it contracts down further, thus bending the stiffened seminal vesicles or compressing the inflamed internal meatus, giving rise to tenesmus and the extrusion of a few drops of blood, the distress slowly subsiding as the bladder partly fills again" (Bryson).

Coming from the prostate, the infection creeps rather uniformly up

from the anterior angle of the trigonum, probably by the lymphatics of the submucous coat. The symptoms are those of cystitis of the neck with bright transitory hemorrhages; per rectum, an unusual sensitiveness of the intervesicular space; distention-reflex is marked, nodules will be felt in the wall below the anterior angle, and nodules in the prostate.

In making a diagnosis, cystoscopy should be practised with the utmost precautions; for all instrumentation leads to aggravation of the symptoms.

Treatment.—Bryson condemns nearly all of the recognized forms of treatment except general and climatic, and concludes: "On the whole, surgery offers very little to these patients, and meddlesome surgery does much harm."

Henry Morris agrees that local treatment is contraindicated except in the later stages. The writer believes that he has found much benefit from median perineal cystotomy, followed by iodoformization and disinfection with methyl blue, and from the rest which the continuous drainage affords.

Catheterization is not necessary to local medication, for sedative and antiseptic fluids can, with a little practice, be injected *per urethram* alone.

Tuberculosis of the Kidney.—Tuberculosis of the kidney occurs in two, or, perhaps, three forms. The first is part and parcel of a general miliary tuberculosis, with which the surgeon has no concern. The second a form of localized miliary tuberculosis, in which one or many points of both kidneys may be affected, the contagium being carried by the blood-stream and settling in the capillaries surrounding the tubules of Ferrein, there giving rise to the development of granulation-tissue, which subsequently undergoes coagulation-necrosis, liquefaction, and, in the presence of pyogenic organisms, pus-formation. The other form is a *tuberculous pyelitis*, or pyelonephritis, or nephrophthisis, which may occur primarily, or from infection by spinal tuberculosis, or by an ascending creeping process from the lower urinary tract. The disseminated tuberculosis is more common in children, and is bilateral. A tuberculous pyelitis often affects one kidney only, and is met with commonly after the age of puberty.

In all cases of cortical or deep-seated implantation, early **symptoms** may be entirely wanting, except, perhaps, polyuria, which may not attract attention, or else may be erroneously ascribed to some other cause. After the disease has existed for some time there may be complaint of pain and dragging in the loin; and bimanual palpation will sometimes discover a kidney-tumor, which may often be made out to be nodular or irregular in outline.

In some cases, the tuberculous granulation-process may cause thickening or swelling of the mucosa and submucosa of the pelvis of the kidney and ureter, and so give rise to swelling and enlargement of the organ. In other cases, and more particularly after considerable periods have elapsed, the pelvis of the kidney may become distended, and the ureter also, and symptoms of hydro- or pyonephrosis may result. In the cases of implication of the pelvis of the kidney, examination of the urinary sediments may serve to indicate the character of

the process; and often in the parenchymatous form, when the disease has proceeded to caseation and ulceration, the detritus, of course, gives evidence of its tuberculous character.

Treatment.—In cases where a tumor can be detected in the loin, lumbar incision affords at once a means of diagnosis and one of the best methods of treatment; for then drainage can be established and local medication carried out. In case of extensive disease of one kidney only, with reasonable assurance of the integrity of the other, nephrectomy may very well be practised, and this, oftentimes, without a preliminary nephrotomy and drainage. For although tubercle here, as elsewhere, gives rise to ulcerative, destructive effects in the course of its development within an organ, without interfering with the utility of surrounding portions, yet, if one kidney be extensively disorganized, experience has shown that the operation of nephrotomy may be attended with as heavy a mortality as that of nephrectomy. Careful observation of the urine and catheterization of the ureters will generally enable one to discover the relative condition of the two kidneys. Therefore, the anterior incision need no longer be practised with a view of determining the condition of the supposedly unaffected kidney.

General roborant treatment, with the employment of antiseptic remedies voided by way of the kidneys, will oftentimes delay the progress of the disease to a very considerable extent. Even if both kidneys be partially diseased, it is still possible to effect some good surgically by the ablation of the diseased parts, followed by suture.

Nephrotomy with curettage, followed by drainage by rubber tubing and iodoform gauze, after irrigation with iodoform-glycerin emulsion, has afforded the writer very gratifying results, and he has found the subsequent injection of iodoform emulsion (10 per cent.) combined with a weak solution of chlorid of zinc and formaldehyd to distinctly diminish the amount of discharge and promote cicatrization.

Nephrotomy to provide an exit for sloughs is a proper precautionary measure before using the tuberculin treatment in nephrophthisis. In doing nephrectomy for tuberculous kidney, it is sometimes necessary or advisable to do a partial or complete ureterectomy.

CHAPTER XI.

THE TECHNIC OF ASEPTIC SURGERY.

The middle-aged surgeon of the present day has witnessed the beginning and the end of a revolution in his art, which represents a greater progress than has been made in all the preceding centuries. He is fortunate who, with personal knowledge of the black septic era, is still alive to enjoy to the full the practice of surgery under the reign of asepsis.

A heavy responsibility rests upon the younger student that no backward step be taken. Let him carefully study the history of surgery before the days of Joseph Lister, that he may thoroughly appreciate the blessings which he now enjoys, and the dangers against which he must be ever vigilant.

The surgeon should appreciate the fact that the introduction of bacteria into the body takes place in nearly all cases through some lesion on the external surface of the body or in a mucous tract, and that without such a wound bacterial invasion is rare; that the commonest source of wound-infection is the pyogenic organism, although a number of these bacteria are required to cause real disturbance of wound-healing; and, finally, that the success of this invasion is dependent not only on the virulence of the germ, but also upon the condition of the soil, the tissues and fluids of the individual, and upon what is termed the power of resistance belonging to the individual. For instance, linear incisions are not as apt to be the seat of infection as contused and lacerated wounds. Persons weakened by disease or worn out by excessive labor yield more readily to infection than healthy individuals. Some individuals possess a greater power of resisting the effects of germ-infection than others.

It is now established that nearly all bacterial infection can be traced to man's tangible surroundings, on which lies dirt of various kinds. The dust and dirt of the street are loaded with germ-life of all kinds, moulds, yeasts, fungi, bacilli, cocci, color- and odor-producing bacteria being present in countless numbers. This vast army of bacterial growth is readily carried by currents of air into every nook and corner, and portions of it are liable at any time to be deposited upon every exposed object, including the clothes and body of every individual. It is no wonder, then, that the surface of the body should be a nidus for germs of all kinds, for it is constantly coming in contact with dust and dirt filled with germ-life. Here bacteria, finding suitable conditions for development—warmth, moisture, and nutrient media—propagate with great rapidity, and eagerly enter the body through abrasions of the skin. Careful surgeons therefore use every means at their command to destroy or avoid bacteria.

For a description of the pyogenic bacteria the reader is referred to the chapter on Surgical Bacteriology.

The word "*sepsis*," from the Greek verb *σήπειν*, was formerly used to define a condition known as putrefaction, the etiology of which had not been discovered. Gradually this term came to be employed to denote the condition found in pus-producing wounds, so that now by sepsis is meant the condition resulting from the introduction of pyogenic bacteria into wounds. All sepsis is due to bacterial invasion.

By the term "*antisepsis*" is meant the adoption of various methods of destroying bacteria or inhibiting them in their growth. Drugs and methods used to accomplish this result are termed antiseptics. True germicides are properly called antiseptics, for they actually kill bacteria. Antiseptics frequently only arrest bacterial development.

Asepsis means absence of germs which produce sepsis. Ideal asepsis is scarcely possible, for it must be conceded that even perfect wounds contain bacteria, which are either non-virulent or too few in number to cause trouble.

It is now generally believed that air is comparatively harmless to wounds, provided that it is moderately free from dust. Of course, the writer does not claim that ordinary air is in any strict sense aseptic, but only that the exposure of an operative wound, during the short period of its formation, to the atmosphere, is not followed by wound-disease. This is demonstrated clinically by our experience, for we frequently obtain long series of wound-healings unbroken by the slightest evidence of infection, although we make no special provision against the free admission of ordinary air to the freshly-made wound. Undoubtedly some bacteria are deposited in the form of dust upon every wound, but ordinarily not in sufficient quantity to result in wound-disturbance. Sea breezes have been shown to be free from bacteria, whereas land breezes are not so. City air is more contaminated than country air. The atmosphere of high mountains is comparatively free from germs, and the air in wet weather is more nearly aseptic than when it is dry; these facts proving that bacteria are especially abundant in the air in places which are either thickly populated or where dust is scattered abundantly by high winds. Gases also of all sorts are free from germs excepting when mixed with dust or spray, and the prevalent idea that sewer gas may cause germ-infection of any sort is incorrect. That water is a source of bacterial infection is generally known, bacteria having a tendency to cling to water, passing from it into the air only in the form of spray. Ordinary cold water is laden with germs and fungi, therefore it must not be brought in contact with aseptic wound surfaces. Water from ordinary hot-water boilers, on the other hand, is comparatively germ-free, and can be used with safety when freshly boiled water cannot be obtained.

It is the aim of the modern surgeon to make and treat wounds aseptically, to do which intelligently implies a thorough knowledge of the causes of infection and demands at least an elementary study of bacteriology. Fortunately, with the various methods of sterilization at our command, it is possible to render all operating paraphernalia free from bacteria, and skin-sterilization, although not perfect, has been of late years enormously improved.

Successful aseptic surgery depends absolutely upon the most painstaking attention to preliminary details. Not only must each individual item in the surgeon's armamentarium be germ-free, but also every individual employed in an operation must realize that complete failure may follow the slightest neglect on his part. The duties of each should be appointed before the operation begins, so that speed may be attained without confusion, thus avoiding loopholes for errors in technic. After the sterilization of hands, objects which have not been disinfected must not be touched. Since the hands are the most frequent source of wound-infection, as few as possible should come in contact with the wound-surface. The dangers of infection are increased by improper hemostasis, accumulation of serum and blood-clot in dead spaces, the presence of detached or poorly nourished particles of tissue, improper drainage, traumatism by rough handling of tissues, irregular incisions, and irrigation of wounds with caustic solutions which produce superficial necrosis, thus interfering with wound-repair. Every surgeon should entertain the absolute conviction that strict attention to perfect aseptic technic will accomplish nearly unfailing success.

The making of wounds with instruments and hands absolutely free from germ-life—that is, thoroughly sterilized, and the complete avoidance of allowing any object not completely sterilized to come in contact with the wound-surface, represents what we mean by aseptic surgery. Disinfectants and antiseptics of various kinds are therefore used, in order that we may so prepare our various instruments and surgical materials that we may work aseptically; and it has been clearly demonstrated that if such preparations are properly made before an operation is begun, and if no fault is committed by the operator or his assistants during the course of an operation, the wound may be made and treated, until healing has occurred, without the use at any moment after the beginning of the operation of antiseptic of any kind.

Ideal asepsis would mean, of course, that not even one bacterium of any variety should find lodgement in the wound. Ideal asepsis, as thus defined, has certainly not yet been attained, but fortunately nearly uniform success can be accomplished, in spite of the entrance into wounds of some germ-life, such as undoubtedly is deposited from ordinary air upon every wound-surface. To diminish the number of these accidental visitors is the special aim of the aseptic working surgeon.

Methods of Sterilization.—It is of the first importance, then, to study carefully the means by which we may so prepare our hands, our instruments, and other materials, as to render them as nearly aseptic as possible. We must begin with the methods of sterilization. These methods have been well classified by Schimmelbusch as follows:

1. Mechanical cleansing.
2. Germicidal agents, chemical and thermal, which destroy bacteria.
3. Agents which arrest bacterial development and prevent germination and multiplication.
4. Antitoxin agents directed not against microbes themselves, but against ptomain-products.
5. Agents not affecting bacteria or ptomaines, but increasing the power of resistance on the part of the patient's tissues.

This classification therefore includes the use of:

1. Mechanical washing and scrubbing, etc.
2. Heat
   - Moist
     - Boiling water.
     - Steam.
   - Dry
     - Hot air.
     - Flame.
3. Chemicals.
4. Antitoxins, etc.
5. The attenuation of bacteria by multiple infection.

In selecting from the various methods of disinfection which ones he shall use, the surgeon must be governed entirely by the conditions under which he is placed. Steam cannot be used for the disinfection of hands, therefore other methods must be substituted. Again, other conditions arise, such as the resistance of the infectious organisms to be destroyed and the disinfecting power of the agents to be employed, the resistance offered by the form and shape of the object, the thickness and kind of dirt, the chemical changes that may occur, the element of time, and the expense of the disinfectant.

Mechanical Cleansing.—While the methods of sterilization are numerous, by far the most useful and most important is mechanical cleansing, not only as applied to the patient, but also to the immediate surroundings. Whatever success was obtained before the discovery of antisepsis was due in a great measure to cleanliness and proper hygienic surroundings. The removal of dirt by washing, scrubbing, and shaving not only disposes of enormous masses of bacteria, but so prepares the various surfaces that other methods of sterilization can be successfully used in attacking such germs as remain.

Heat.—As a general disinfectant no agent is so valuable as heat, and only when it cannot be applied in one form or another should chemical sterilization be made use of. Heat may be applied either in the form of the flame or of boiling water. The actual cautery may be used for sterilizing septic surfaces, the flame for the sterilization of instruments; but its use for this purpose is generally to be condemned, as it discolors and injures metal.

The anthrax organism is one of the most resistant pathological germs, yet it is destroyed by boiling water in two minutes. Bacteria without spores have yielded to this agent in from one to five seconds, and the most resistant bacteria in from fifteen to thirty minutes; therefore the practical utility of boiling water is evident, for it is not only very efficient but inexpensive, constantly at hand, and requires little time in preparation. Its use, however, is limited to the preparation of solutions, suture-materials, instruments, and dressings.

Steam.—As a sterilizing agent, steam possesses a higher value than hot air, as it requires a shorter time and is more thorough. The temperature necessary is lower, and it does not burn dressings and clothing, nor render them fragile or useless. Live steam will kill anthrax spores in from five to fifteen minutes. Hot air takes much longer to accomplish the same object. Steam may be used in the following forms for disinfecting purposes: *a.* Quiescent—simple steam; *b.* Circulating freely—live steam; *c.* Under pressure—high-tension steam; *d.* If raised by flame at 100° C.—superheated steam.

Of these various forms, live steam has proved to be more germicidal than simple steam, and that known as high tension is the most potent of all. Various appliances called *steam sterilizers* are found in the market. One should be familiar with the requisites of a proper sterilizer, and a brief description of those generally believed to be most suitable for hospital and private work is here given. The requisites for the best sterilizer may be summed up as follows: 1. Proper shape—prevention of dead spaces; 2. Saturated steam; 3. Prevention of condensation; 4. Pressure; 5. An equable temperature; 6. Devices for drying dressings; 7. Cheapness and ease of manipulation.

Whether the sterilizer be large or small, it is advantageous to avoid square corners, for in these air is apt to collect, and steam does not penetrate satisfactorily, so that portions of materials occupying such spaces are not sterilized properly.

The length of the sterilizer must also be limited, for the longer it is, the greater is the difficulty of maintaining an equable temperature. Steam filling such a reservoir should be saturated—that is, there should be no admixture of gas. This can be accomplished in either of two ways—by creating a vacuum before admitting the steam, or by admitting steam from above. The vacuum drives the air not only from the chamber, but also from the objects enclosed, and thus indirectly helps to heat these, both by preventing condensation and also by aiding future penetration by raising the pressure of steam forced in later. Thus, with a preliminary vacuum, steam at ten pounds' pressure is as good as steam at twenty pounds without a vacuum. For all practical purposes, however, the admission of steam from above will drive the air out sufficiently well. Special emphasis is laid upon the admission of steam from above, because in this way air will be forced out steadily and uniformly, steam being lighter than air; whereas, if it comes from below, the steam passes up in eddies and escapes in part, without forcing the air out completely. As the live steam passes into the sterilizer, there is a tendency for it to give up its latent heat, not only to the walls of the chamber, but also to the dressings enclosed. The result is condensation and a formation of drops of water, which line the wall of the sterilizer and wet the dressings. To exclude this defect absolutely is very difficult, but certain methods are made use of, which render damage from this source an infrequent occurrence. In the first place, all sterilizers should be surrounded with a steam jacket, through which steam hotter than that in the chamber should pass, and the element of condensation will thus be avoided. This jacket has the advantage not only of preventing condensation, but, as it becomes superheated, the steam is kept in circulation by the effect of this increased temperature on the sides of the jacket. Objects before being brought in contact with steam should be thoroughly heated, so that when they are exposed to the vapor, condensation will not be as likely to occur. Preparatory warming does not entirely prevent condensation, because the hot air does not, as a rule, penetrate to the center of the objects to be sterilized, and the cold air in the center may cause some condensation. With a steam jacket, however, the steam in the chamber is inclined to be superheated, and the extra heat is sufficient to cause re-evaporation of moisture, so that objects eventually come out dry and little harmed. It has been conclusively shown that, in order to get the greatest benefit from steam sterilization, the live steam should be kept under pressure. High-pressure steam, and by this is meant steam under pressure of from ten to fifteen pounds to the square inch at 240° F., has the advantage over steam at low pressure that it is more penetrating and more germicidal. It is also less liable to condensation and can be easily obtained from any neighboring steam-pipes, so that special apparatus for its manufacture is not required. Its disadvantages are increased care and expense in the manufacture of sterilizers, and more care required in handling them. The best penetration can be obtained by relaxing the pressure during sterilization and refilling the chamber with steam several times, thus driving out the air in the materials to be disinfected. The maintenance of an equable temperature throughout the process of sterilization in every corner of the sterilizer is very necessary; otherwise, disinfection will not be complete, and it is only by keeping high, steady pressure, by preventing condensation, and by obtaining a complete liberation of air from the chamber, that such a temperature can be procured. Should the dressings be found moist after being sterilized, an easy method of drying consists in turning off the steam in the chamber and continuing that in the steam jacket. Dressings may then be readily dried.

The following articles may be exposed to steam for sterilization: Dressings, towels, gowns, suture-material of some sorts, solutions in glass jars, gauze impregnated with chemicals, such as iodoform and balsam of Peru, and infected clothing. Rubber and leather cannot be

sterilized by steam without injury. Before exposing articles to steam sterilization care must be taken not to pack them too tightly together—that is, air spaces should exist between the different objects. Articles should not come in contact with the sides of the sterilizer; otherwise, drops of moisture which accumulate upon the lining may fall upon them. All materials should be heated before they are exposed to steam. The time required for steam sterilization is dependent upon several different conditions, as, for instance, the amount of pressure, the temperature, the compactness of the articles to be disinfected, and the nature and virulence of the organism to be destroyed. As a rule, to secure a perfect germicidal action, articles must be exposed for fifteen minutes under ten pounds' pressure and a heat of 240° F. for three consecutive periods twenty-four hours apart, in order to allow for the development of spores, which are more resistant than the germs themselves. For ordinary purposes, the common vegetative germ may be killed if sterilization is continued for three-quarters of an hour on one occasion.

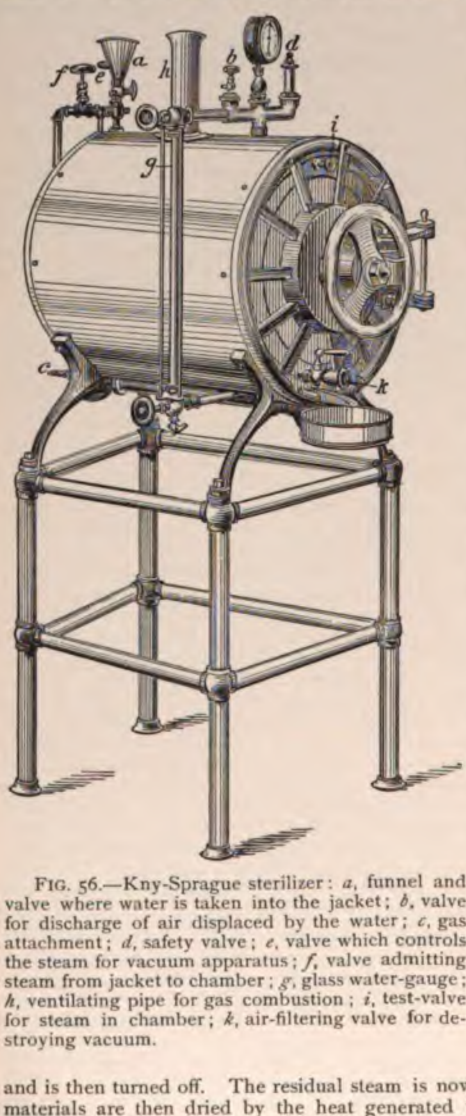


FIG. 56.—Kny-Sprague sterilizer: *a*, funnel and valve where water is taken into the jacket; *b*, valve for discharge of air displaced by the water; *c*, gas attachment; *d*, safety valve; *e*, valve which controls the steam for vacuum apparatus; *f*, valve admitting steam from jacket to chamber; *g*, glass water-gauge; *h*, ventilating pipe for gas combustion; *i*, test-valve for steam in chamber; *k*, air-filtering valve for destroying vacuum.

For hospital work the Kny-Sprague Sterilizer (Fig. 56) has proved to be as useful as any. It consists of a cylindrical chamber, surrounded by a steam jacket, attached to which is an arrangement for creating a vacuum when required. The water is heated from beneath by gas, or by steam collected through pipes from some neighboring boiler. The steam jacket, half-filled with water, generates the requisite amount of steam, under pressure of from ten to twenty pounds, at a temperature of from 230° to 260° F.; then the air in the sterilizing chamber is exhausted by the vacuum apparatus, and the steam turned in. The steam is allowed to circulate freely for from fifteen to thirty minutes, according to the density of the objects exposed, and is then turned off. The residual steam is now removed by creating a vacuum, and the materials are then dried by the heat generated in the jacket surrounding the chamber. This will require from ten to twenty minutes. By turning a valve, filtered air is allowed to pass into the chamber, thus relieving the vacuum, and the materials are removed dry and sterile. Smaller sterilizers for private work are made of the same pattern, which answer the purpose admirably. Where a condensation instrument and steam sterilizer without pressure are desired, the Schimmelbusch apparatus is found to be very efficient. In this the

steam escaping from the water used for boiling instruments sterilizes the dressings. The dressings are ranged in packs constructed after the manner described in the chapter on Dressings, and are then placed above the apartment used for the sterilization of instruments. Hot-air sterilizers have proved to be of no practical value in surgery, and therefore need not be here described.

Chemical Disinfection.—Chemical disinfection, although inferior to mechanical and thermal methods, nevertheless must be employed under certain conditions. Chemical antiseptics are not generally used simply for the purpose of obtaining an aseptic condition prior to operation. A chemical, in order to be an ideal disinfectant, must have certain properties. It must be—1. Soluble and penetrating; 2. Actively germicidal; 3. Effective in a brief time; 4. Non-poisonous; 5. Neither destructive to materials nor irritating to wound-surfaces; 6. Not decomposable, and not rendered inert by condensation; 7. Inoffensive in odor; 8. Inexpensive.

No chemical combining all these valuable qualities has yet been discovered. Only a few chemicals have germicidal action on anthrax spores, even when the latter have been exposed to them for twenty-four hours. These are—bichlorid of mercury, iodin, chlorin, bromin, trichlorid of iodin, and creosote mixed with sulphuric acid.

A few are germicidal after continuous contact for a number of days. Such are—carbolic-acid solution, 5 to 100; ligneous vinegar; chlorid-of-lime solution, 5 to 100; turpentine; formic acid; chlorid-of-iron solution, 5 to 100; quinin; muriate solution, 1 to 100; arsenious-acid solution, 1 to 1000; muriatic-acid mixture, 2 to 100; sulphuric ether.

The vegetative forms of bacteria are not so resistant, and will succumb even to some of the weaker chemicals; but still the antiseptic power of these drugs is far below that of heat, for it has been found that the Staphylococcus pyogenes aureus is not completely destroyed when subjected for fifteen minutes to the action of a 1 to 1000 bichlorid-of-mercury solution.

In regard to the value of chemicals for disinfection, laboratory experience sometimes produces different results from those obtained in surgical work, because the conditions are different. For instance, in laboratory experimentation a few germs are exposed to a large quantity of the chemical; but in surgical work the reverse holds true, for in the latter case sterilization is attempted upon masses of bacteria hidden away, often in impermeable matter, such as coatings of fat, so that very little antiseptic ever reaches many of the germs. Then, too, most antiseptics on coming in contact with wound-discharges break up into combinations which are inert, uniting more commonly with the albumin contained in wound-discharges. While comparatively few different chemical antiseptics are at present made use of, the more important ones that have been recommended of late years will be now enumerated:

Chemicals for disinfection are used either as powders or in solutions of a watery or oily character, and they are here classified according to their germicidal power:

Bichlorid of mercury is the most active of all. It occurs as a white, crystalline, odorless powder, very poisonous, and soluble to saturation in 1 to 16 of cold water, 1 to 3 of alcohol, and is also freely soluble in ether and

volatile oils. It promptly decomposes on touching metals, and therefore cannot be used for sterilizing instruments, nor should it come in contact with metallic apparatus of any sort. Mixed with ordinary water, it has been found that earthy substances, carbonic alkalies, combine with the salt, causing an inert precipitate. This is to be avoided by using hot distilled water and adding equal parts of salt and one of the following substances: Sodium chlorid, tartaric acid, hydrochloric acid, or salicylic acid, to a given quantity of water. The solution, even with distilled water, soon becomes inert on standing, on account of the formation of an oxychlorid. Light also, after a short time, causes a partial decomposition, precipitating calomel, and forming hydrochloric acid. A 1 to 1000 solution is used in the disinfection of skin-surfaces. For this purpose it can be actively useful only after oily material has been removed from the area to be disinfected. In sterilization of jars, bowls, etc., before operation, corrosive sublimate is valuable in the same strength, also in the preservation of catgut in alcoholic solution, rubber tissue, sponges, and tubing. Bichlorid of mercury should not be used on wound-surfaces for several reasons: In the first place, it causes superficial necrosis, even when employed in the strength of 1 part to 10,000, and thus favors a multiplication of micro-organisms, and when it comes in contact with the albumin in pus, blood, or in any tissue, the salt decomposes, forming an inert salt of albuminate of mercury, which simply surrounds each spore or bacterium, forming a capsule, and thus further disinfection is prevented.

Poisonous symptoms have frequently been noted as a result of the continued use of this drug. When used continually by the surgeon, the hands become blackened, rough, and cracked, and in that condition are especially liable to harbor bacteria. Local irritation, resulting in an angry dermatitis, often follows the application of moist bichlorid dressings, and when solutions of bichlorid have been used for continuous irrigation, symptoms of violent gastro-enteritis, colicky pains, vomiting, and salivation sometimes occur. For ease of transportation corrosive-sublimate tablets are sold. The outer coating of such tablets after a time changes to calomel, and thus the strength of the tablet becomes lessened. A 10 per cent. solution is more useful, 2 drams of which, added to a quart of water, cause a solution of the strength of 1 part to 1000 of the pure salt. About 7½ grains added to the pint make a solution of the same strength.

Carbolic acid, Lister's original disinfectant, is a local caustic, coagulating albumin, and, like corrosive sublimate, should not be used on wound-surfaces, on account of its irritating effect. It is not nearly as powerful a germicide as bichlorid of mercury, requiring from fifteen to twenty minutes for the destruction of vegetative bacteria. It has the advantage of permeating oily substances and of retaining its stability. It is cheap, a good deodorizer, and has a slight anesthetic effect on tissues.

When the hands of the operator come in contact with carbolic-acid solution for any length of time, they become very tender, rough, and cracked. Poisonous effects may occur, both locally and constitutionally. Continuous use, as in the form of hot poultices, often causes an acute inflammation and desquamation, and strong solutions may pro-

duce gangrene. It is especially poisonous to children. When the drug is applied to wound-surfaces for some time, sufficient absorption may take place to cause general weakness, sweating, increased salivation, anorexia, nausea, vomiting, headache, vertigo, and irregular breathing, with rapid and feeble pulse. If the absorption of carbolic acid continues, the patient passes into coma, preceded by clonic spasms, and followed by collapse and death. The urine soon gives a characteristic appearance, becoming green, then brown and smoky, and an absence of the normal amount of sulphates is noted.

Other antiseptics of minor importance are lysol, creolin, salicylic acid, boric acid, potassium permanganate, oxalic acid, and chlorin water. Of these, lysol, creolin, and salicylic acid have many of the characteristics of carbolic acid, but no special advantages. Potassium permanganate, oxalic acid, and chlorin water are of interest chiefly from their use in some of the chemical processes for the disinfection of the hands. Boric acid is used simply for irrigation of mucous membranes. For this purpose salt solution is better.

Hydrogen peroxid has become very popular in the treatment of suppurating wounds. It is a clear fluid, the full strength being called 15 volume solution, by which is meant that 15 volumes of oxygen are contained in each volume of the liquid in very feeble combination. The precise value of this drug as an antiseptic has not been determined. The bacillus of tetanus has been cultivated in a full-strength solution. It is supposed to act upon the albuminoid elements, on which the bacillus lives, through its power of oxidation. Strong solutions are non-poisonous, but if it is used continually on wound-surfaces, the latter become sluggish and pale, and the tendency to heal seems to diminish. As a cleansing agent and deodorizer for foul-smelling and suppurating wound-surfaces hydrogen peroxid is very valuable, if not used for too long a time, such wounds becoming healthy looking and inoffensive as the discharges are oxidized. When hydrogen peroxid is applied, ebullition occurs until the drug is exhausted or the pus has oxidized. It should not be used on fresh aseptic wound-surfaces. For irrigating suppurating cavities hydrogen peroxid is very efficacious. It should be kept in the dark and cold. Variability of strength, ready decomposition, and expense limit the use of this agent. For ordinary purposes the strength made use of is from 3 to 5 per cent.

Sodium chlorid, or common-salt solution, in the physiological strength of $\frac{6}{10}$ of 1 per cent., rendered sterile by heat, is mentioned last, not on account of its minor importance, but because it is only indirectly antiseptic. It is prepared in the following manner: 6 drams of sodium chlorid, first sterilized by heat, are added to 1 liter of distilled water, which is contained in an oval glass flask that has also been sterilized. This flask should not be entirely filled, in order to allow for expansion, and should be sealed with absorbent cotton and covered with a handkerchief of gauze fastened tightly to the neck of the flask, so as to keep the lips of the bottle sterile. The solution thus made should be exposed to steam sterilization for one-half hour on two successive days.

For simple mechanical irrigation salt solution is of the greatest value, especially when applied to mucous membranes, fresh wounds, and serous surfaces, and inasmuch as it is mild and soothing, non-

poisonous, and easily obtained, is by far the best irrigating fluid that can be employed. It is the only chemical preparation that does not produce irritation when brought in contact with wound-surfaces. After its use aseptic wounds may be closed, for the tissues will have suffered no more injury than is caused by the ordinary operative manipulation, and septic tissues already weakened by bacterial poisons will be much more capable of resisting pathogenic organisms than if exposed to caustic applications.

During operations salt solution is used for clearing away blood-clots, one of its effects being to cause various tissues to become more clearly defined, so that the surgeon is enabled more readily to distinguish the proper landmarks. Its use in skin-grafting, and also as an intravenous infusion, is well known.

Alcohol is a preservative agent and not a germicide, although it prevents to a certain degree the growth of bacteria by dehydrating the tissues. Its use in surgery is limited to the preservation of materials, such as catgut which has been previously sterilized, and to the sterilization of the skin through its power of removing superficial layers of fatty material and withdrawing water from the tissues.

Ether and *turpentine* are used principally for the purpose of cleansing the skin by removing dirty and fatty substances.

Numerous *powders*, said to possess more or less value as antiseptics, have been recommended from time to time to the profession. Aseptic wounds can certainly not be benefited by the application of any powder, and much better applications can be made to septic surfaces. No powders are germicidal, as, in their original form, they are non-penetrating, and bacteria can live even when surrounded by the most powerful so-called antiseptic powder, if it is dry. When applied to a septic surface, the absorption of a little moisture causes the formation of an artificial scab, and so prevents the escape of septic secretions from the wound-surface. This dry covering renders the next cleansing of the wound difficult, and its mechanical removal produces fresh traumatism. Moreover, the absorption of such powders is only limited with certainty by the amount that is applied, so that those which are poisonous in quality are capable of doing serious harm.

Iodoform, however, deserves especial attention, because it is at present in very general use. Many surgeons rarely apply it, and it probably will not long occupy a position of importance in aseptic work. Iodoform is a light-yellow, crystalline substance, of peculiar odor, very poisonous, soluble in alcohol, ether, chloroform, and in some oils and fats. It is not soluble in water. Iodoform is not actively germicidal, but its application seems to render the wound-area unsuitable for the propagation of the bacteria of infection. Perhaps its action is due to the decomposition which takes place when it comes in contact with the ptomaïns and leukomains produced by bacteria. Iodin being eliminated renders the wound unfit for the growth of bacteria. Both the Streptococcus pyogenes albus and the Staphylococcus pyogenes albus have been often found to flourish in iodoform powder when it is not in contact with living tissues; therefore, before its use, it should be rendered sterile by a soaking in 1 to 1000 bichlorid-of-mercury solution for at least five minutes. Iodoform is applied to foul septic wounds either as

a powder or in the form of iodoform gauze, and certain mixtures containing iodoform are made use of for injection into tubercular and other lesions. Iodoform in any form should not be applied to an aseptic wound. When used as an injection, mixed either with glycerin, vaselin, or ether, the preparation should always be carefully sterilized. The preparation of iodoform gauze is described with other dressings. The disagreeable odor of the powder can be mitigated by mixing with it burned coffee powder, or some aromatic oil. On account of its odor, iodoform has been supplanted to some extent by drugs of the same general character, but with a less disagreeable smell, of which the following are the more important: Dermatol, iodol, aristol, salol, soziodol, sulphaminol.

Dermatol and aristol are the best of these, and are useful sometimes for application to simple excoriated surfaces.

Iodoform is capable of producing active local and constitutional poisonous effects. Locally, it sometimes gives rise to a violent dermatitis, requiring its immediate disuse.

Schede describes the constitutional poisonous effects as follows:

1. High fever.
2. Fever with gastro-intestinal irritation, rapid pulse, and depression of spirits.
3. Very rapid compressible pulse without fever. This is a dangerous form.
4. Very rapid pulse and very high fever.
5. Great depression, collapse, early death.
6. Cerebral symptoms somewhat resembling those indicating meningitis.

In most cases suffering from iodoform poisoning, iodin may be detected in the urine by adding a small quantity of commercial nitric acid and a little chloroform. Upon shaking the mixture, the chloroform will acquire a purple color, due to the free iodin which is liberated, and will settle as a purple layer at the bottom of the vessel.

Other powders, such as boric acid, calomel, europhen, oxid of zinc, lycopodium, subnitrate and subiodid of bismuth and naphthalin, are occasionally used, but have no real value in the treatment of wounds. Oils and ointments, whether they contain antiseptics or not, should be thoroughly sterilized before use, otherwise they furnish an excellent medium for the growth of bacteria. Fatty materials, in general, protect bacteria from the destructive action of chemical antiseptics. They are certainly of value as soothing applications to some inflamed surfaces, and by softening render the removal of dry scales and masses of epithelium more easily accomplished.

Sterilization of Water.—Water may be rendered free from germ-life by the addition of chemicals, such as carbolic acid, bichlorid of mercury, etc., but for application to wound-surfaces the chemicals used in sterilizing water are undesirable. Water may be rendered perfectly free from bacterial life by boiling. Even when boiled, however, dirty water, although in this manner completely sterilized, contains foreign material, which is not desirable for wounds. Water should therefore, previous to its final preparation, be either distilled or filtered. It may then be sterilized by boiling for half an hour or even a much shorter

time. With a sterilized dipper it may then be transferred to properly prepared pitchers or bowls. When handled in this manner, however, water of an absolutely perfect quality cannot be furnished; for its exposure to the air, in transferring it from one vessel to another, and the use of different utensils in the same process, necessarily expose it to the entrance of some bacilli. To be rendered absolutely sterile and to remain in that condition until brought to the operating table, water must be prepared as follows:

Glass flasks, which have been perfectly cleansed, are to be filled nearly to the top with pure filtered or distilled water. The flasks are to be plugged with cotton, over which a piece of gauze should be tied to prevent displacement of the cotton and contamination of the edge of the flask-mouth. The flasks are then to be subjected to steam-sterilization under pressure, exactly as dressings are, and should remain in the sterilizer for at least one-half hour. This process should be repeated two days in succession, in order that spores which may have survived the first boiling may be destroyed by the second. Water prepared in this manner may be kept unchanged for an indefinite length of time, if the plug of cotton is not removed from the mouth of the flask. It seems impossible to provide a water-sterilizing apparatus from which water may be drawn through a tap in an absolutely perfect condition, for the tap itself is constantly exposed not only to the atmosphere but to contact with hands and other objects. Still less easy is it to arrange that boiled and sterile water may be led from a reservoir through pipings to different parts of a building and delivered at any desired point in a sterile condition, the difficulty being that the pipes through which the water is led cannot be kept absolutely free from germ-life; for spores which have escaped destruction in the first boiling are liable, before water is again drained at the end of the pipe, to develop more or less actively in the pipe itself.

Water, however, drawn from any hot-water boiler is sterile, and may be freely used in surgery, provided only that the pipe through which it is drawn is frequently flushed out with boiling water just before the supply is called for. Hospital operating rooms should therefore have close by them a boiler, in which filtered water may be freshly boiled every day. The delivery pipe should be short and well protected. Before using this water, the delivery pipe should be cleansed by drawing off a number of gallons of water.

Ligatures and Sutures.—Ligatures and sutures are made from catgut, kangaroo-tendon, silk, silkworm-gut, horse-hair, and silver wire.

Catgut approaches most nearly to the ideal suture and ligature. Nevertheless, it has been much criticised, chiefly on account of the great care required in its sterilization, and for this reason some surgeons have nearly dispensed with its use.

Silk is more easily prepared, but its disadvantages, as occasionally shown, far outweigh the care necessary in thoroughly preparing catgut. Theoretically, silk, when used for buried sutures and ligatures, becomes encapsuled in the tissues, and remains there without creating any subsequent disorder. It is, of course, in this condition a permanent foreign body, and if the wound in which it is used could be ideally aseptic—that is, absolutely free from bacteria of any kind, and if the patient could forever remain absolutely aseptic, buried silk sutures and ligatures would never give rise to disturbance in the tissues. Practically, however, such foreign bodies not infrequently, at periods quite distant from the time of their application, invite local bacterial disturbances resulting in abscesses or obstinate sinuses.

Catgut which has been thoroughly prepared and applied in an

aseptic wound and according to perfect aseptic technic is soon absorbed, and rarely, if ever, causes wound-disturbance. It has been claimed by many writers that catgut may be absorbed before its purpose has been fulfilled, and for this reason the use of a non-absorbable suture has been recommended. It should be remembered, however, that the surgeon uses sutures in the deeper parts of a wound only as a temporary means of approximation, and that he really depends for permanent union on the growing together of the parts thus temporarily approximated. Such union of parts that have been drawn together takes place, if at all, within the period of life of the catgut; for while the smallest sizes of catgut are absorbed at the end of four or five days, larger sizes may be used, which, when properly prepared, last from ten days to three weeks. If positive union has not occurred within such a period, non-absorbable sutures, which continue to exert tension, or which are obliged to resist continued tension, must soon fail in their purpose, for all living tissues subjected to the pressure accompanying the long-continued tension of a suture yield by pressure-necrosis and absorption. As a buried suture, nothing can equal catgut, which performs its function for a sufficiently long time and then completely disappears. If, during the early process of union between the deep parts of a wound, additional support is required, it may be readily given by means of non-absorbable sutures, such as silk, or silver wire, or horsehair, which should in all cases emerge through the skin, in order that they may be readily removed when their object has been accomplished. It is probable that when wound-disturbances, such as skin-abscess, have followed the application of catgut which has been properly prepared, the catgut had become infected by handling. No surer means of infecting catgut could be found than rolling it between the finger and thumb of a naked hand while threading a needle. Even where it is desired to hold bone-fragments together, as in cases of fracture of the patella or resection of the knee-joint, heavy catgut answers every purpose. In such cases the suture is only a temporary support, and is valuable only up to the complete application of the dry fixation-dressing. In these bone-cases, absorbability of the approximating suture is a most desirable quality. For ligatures and all buried sutures catgut is certainly to be highly recommended. With this opinion, however, many prominent surgeons do not agree, much preferring, in all instances, the use of silk. For the skin-suture, which is not buried, silk has superior qualities. Fine silk is stronger than catgut of a similar size. It is more pliant and leaves a neater suture-line, since it does not swell, as catgut does, through absorption of moisture from the tissues. The final healing, therefore, of the skin-wound has a better appearance after the use of silk than after the use of catgut. Catgut may be procured in skeins about thirty yards long, numbered according to the size. Double zero is the smallest, and this is suitable for very fine sutures and ligatures. Single zero and No. 1 are the next two sizes, and these are sufficiently strong for small vessels and peritoneal sutures and for other cases where only very temporary apposition is required. No. 2 forms a firm, strong suture. Nos. 3 and 4 are really heavy and powerful, and are used in tying large pedicles and in bone-work. When the tissues to which catgut is applied are exceedingly

delicate, such as omental masses, intestinal surfaces, walls of vessels, etc., the suture should be softened by immersion for a few seconds or a half-minute in sterilized water or in sterilized salt solution. If this is not done, stiff and wiry catgut may cut directly through the tissues which the surgeon desires merely to compress. Probably some intra-peritoneal hemorrhages occurring after operation have been due to neglect of this precaution.

Sterilization of Catgut.—Three different methods for the sterilization of catgut are here given, and they have all proved to be satisfactory.

The *cumol method* is theoretically the best, as it is simple and inexpensive, and bacteriological experiments, as well as its indirect application, have shown that it produces complete sterility. The temperature of the fluid during the preparation of catgut by this method requires careful watching. The modified form of the method, which is here given, was first employed at the Johns Hopkins Hospital, and is thus described in an article by Drs. Clark and Miller of that institution:

Cumol is an inflammable but non-explosive hydrocarbon, with a boiling point of about 170° C. When the cumol fluid is brought to a temperature just short of its boiling point, all spores introduced into it are destroyed, as a higher temperature is reached than when alcohol is made use of, and there is no waste of cumol, as the fluid is kept below its boiling point. The catgut is rolled upon glass spools, and these are put into a glass beaker. The beaker stands in a sand-bath heated with a Bunsen burner. A layer of cotton should be placed at the bottom of the beaker, on which the catgut may rest. The top of the beaker is to be covered with a piece of cardboard. Through a hole in the center of the cardboard a thermometer passes. Heat is now applied to the sand-bath, and the temperature of the catgut slowly raised to 80° C. In this manner all moisture is driven out of the catgut. This degree of heat is maintained for one hour. Cumol at a temperature of 100° C. is now added to the beaker, completely covering the catgut. The temperature is then increased to 165° C., and kept at that point for one hour. The fluid is now poured off, and the catgut is allowed to dry in the beaker on the sand-bath at a temperature of 100° C. for two hours. It is then to be transferred to sterile jars or test-tubes until needed, or it may be preserved in sterile alcohol.

The *alcohol method* is applied as follows: The alcohol must be boiled under pressure at its normal boiling point, which is considerably below 100° C. This is easily done, but the apparatus must be made very accurately and is expensive. It consists of a heavy metallic cylinder or jar, the top fitting very perfectly and held in place by a bar, which admits of the top being firmly held in position by a powerful screw. The jar is partly filled with absolute alcohol, in which the catgut in skeins or on spools is immersed. The top of the jar is to be firmly screwed down and the entire cylinder buried in boiling water for one hour.

A *third method* is simple and requires no expensive apparatus, but the time of preparation extends over a period of several weeks. Glass spools with the catgut wound upon them are placed in a jar of benzin for four days, then in a jar of ether for two weeks. They are next soaked in oil of juniper for two weeks, in order that all animal fats may be removed. The spools of catgut are passed next to a glass jar containing absolute alcohol and provided with a screw top. This is put in a water-bath, and the water allowed to boil for a half-hour. During the boiling the screw top is only lightly held in place. After the termination of the boiling the top of the jar is screwed down tightly and the jar removed from the bath. On the following day the lid should be loosened and the boiling for a half-hour repeated, and again a similar process is gone through with on the third day. During the three boilings it will probably be found necessary to add some fresh alcohol to compensate for that lost by evaporation. After the third boiling, the lid having been firmly screwed down, the catgut is ready for use or for continued preservation.

The *suture-jar* is a square glass box having a glass rod running horizontally down the middle, which serves as an axle on which the spools of catgut are threaded. Before placing the spools in the suture-jar, the latter is sterilized by boiling, and is then filled with sterile absolute alcohol. The catgut may be reeled off the spools as required. During an operation, sutures and ligatures are cut with a pair of scissors set aside for that sole purpose, and the cut pieces are kept in a separate dish. No instrument which is being used in an operation, no matter how clean the case may be, should be employed to cut the catgut from the spools or allowed to enter the jar. If these directions are desirable, how much more important is it that the sutures and ligatures should not be handled with naked fingers! The

suture-jar has a close-fitting glass cover, and the spools may be allowed to remain in the jar from day to day until used.

Chromicized Catgut and Kangaroo-tendon. — Next to catgut, prepared as already described, the most popular soluble suture-materials are chromicized catgut and chromicized kangaroo-tendon. It is true that, after they have been submitted to a bath of chromic-acid solution, catgut and kangaroo-tendon are far less readily absorbable. This form of suture-material is capable of lasting from four to six weeks. The method of preparing chromicized catgut and kangaroo-tendon is as follows:

The suture-material, after having been freed from fat, by being washed in ether, is treated to a bath of a 4 per cent. aqueous solution of chromic acid. After remaining in this bath for twenty-four hours, it should be dried in a hot-air oven.

The rest of the process is the same as already described under the head of the Cumol Method.

Silk.—Silk thread of any reliable make is suitable for sutures. Black is the preferable color, as it is most readily seen. All sizes, from that which is exceedingly fine to that which is very heavy and powerful, can be obtained. After winding on glass bobbins or spools, silk should be boiled for a half-hour in a 1 per cent. sodium-carbonate solution, when it will be ready for use. Or this method may be adopted: The bobbins of silk may be put in a glass ignition- or test-tube, the end of the tube being plugged with cotton. The tube is then to be submitted to ten pounds' pressure in a steam sterilizer for a half-hour, and the process repeated on the following day. The test-tubes are kept plugged till the suture is needed.

The objection to the simple boiling process is that it diminishes the strength of the silk, whereas sterilization by steam under pressure has not the same disadvantage.

Silkworm-gut.—Silkworm-gut is purchased in bundles of twenty or thirty strands, which are about twelve inches long. The strands should be placed in glass tubes and submitted to steam sterilization. Silkworm-gut may also be boiled in plain water for a half-hour. A soda solution should not be used, as it renders the gut soft and swollen and impairs its strength. Silkworm-gut is largely used, as it is much stronger than catgut, but it is much less pliable and is not absorbable. It makes an excellent suture for skin, as it is smooth and homogeneous, not absorbing serum as silk does, nor entangling bacteria. It possesses some of the good properties of silver wire.

Horsehair.—Horsehair makes an excellent suture, and the finer grades leave a very neat scar. The hairs are cut into foot lengths, well washed with soap and hot water and then rinsed in alcohol.

This material is sterilized by steam under pressure.

Silver Wire.—Silver wire has its chief value as a heavy retention-suture. Usually sterling wire, of about No. 20 standard gauge, is used. It is to be prepared, after a thorough scrubbing in soap and water, by being boiled, as the instruments are, in a 1 per cent. sodium-carbonate solution for a half-hour, or it may be heated in an alcohol flame.

The latter method offers the advantage that it anneals the metal, and thus renders it less liable to break when twisted.

Sponges and Pads.—Sea-sponges, although more expensive and troublesome in preparation, are preferable to any of the substitutes as an absorbent of fluids. For ordinary use in removing blood from the field of operation, the small globular hand-sponge, about two inches in diameter, is suitable. Sponge has great absorbing power, and its elasticity renders it capable of rapidly taking up a large amount of blood. It is also valuable in forming a dam or wall to prevent the excursion of septic material or other fluid into adjacent portions of the peritoneal cavity during operations involving the abdomen. As it instantaneously absorbs and collects fluid which touches it, no fluid can pass it until the sponge has become saturated. As a substitute for the sea-sponge, some surgeons use gauze and cotton mops. Such a mop is made with a six-inch-square piece of gauze, in the center of which is placed a ball of absorbent cotton two inches in diameter. The gauze is gathered up about the ball of cotton and tied like a sack with a piece of string. Mops are less expensive and easier to sterilize than sponges, and some consider that their sterilization can be made more perfect. They have the disadvantage, however, that they do not absorb nearly as rapidly. As pads to keep intestinal coils from invading the field of operation, large flat sea-sponges, called by surgeons laparotomy-sponges, are the most convenient. An economical and very efficient substitute is a flat gauze pad. These pads are six inches square, and consist of four or five layers of gauze stitched together, at one corner of which a loop of tape is sewed. After the pad is put in place in the abdomen, a clamp is put on the loop, which prevents the pad from being forgotten, and so unconsciously left behind. Mops and pads are sterilized like dressings, and should be invariably destroyed after use. It is true that sponges may be resterilized, but the safer method is invariably to make use of a fresh set at each operation.

Sea-sponges are prepared as follows: They are first beaten with a wooden mallet to get rid of shells, sand, etc., and are then soaked in a solution of hydrochloric acid, 1 : 64, for twelve hours. Lime deposits are thus destroyed, and the sponges partially bleached. They are then to be washed in warm water, the water being changed frequently, until it is no longer clouded by the washing. They are then soaked for fifteen minutes in a saturated solution of permanganate of potash, squeezed, and placed in a warm saturated solution of oxalic acid; there they are allowed to remain until every trace of the color of permanganate has disappeared. Usually this object will be accomplished in one half-hour. A thorough rinsing in sterile water should follow, the hands being covered by sterile rubber gloves. The sponges are then put in a solution of 1 : 1000 bichlorid of mercury, and kept there for twenty-four hours, from which solution they should be removed, squeezed, and preserved in sterile jars containing 1 : 20 carbolic-acid solution. At the time of operation a sufficient number of sponges are to be removed from the jars, squeezed out, and put in a bowl of normal salt solution. From this bowl they are handed to the surgeon as they are required. When saturated with blood, they are handed back to the nurse, who rinses them out in another bowl of normal salt solution, when they may be again used as before.

Dressings.—The list of materials which have been used with the special object in view of absorbing wound-discharges is a very long one, almost every inexpensive absorbent material having been applied by one surgeon or another, either as an immediate dressing to the wound or as an enveloping cushion or pad. Oakum, jute, peat, wood-wool, moss, even earth, have all been used as an absorbent dressing. At present, wound-dressings are represented almost universally by two

materials—cheese-cloth, or what is commonly called "gauze," and absorbent cotton. These also were at one time applied after having been saturated with various antiseptics, such as bichlorid of mercury, carbolic acid, salicylic acid, boric acid, etc.

In aseptic surgery the present practice is to apply such sterilized dressings as are suitable completely to protect the wound from traumatism and readily and completely to absorb such discharges as occur, recognizing the fact that as soon as the dressings have become partially saturated they should be entirely removed and replaced with fresh sterilized material. Practically, we find that discharges absorbed into sterilized dressings do not become contaminated through the air unless the dressings have been left so long in place that they have become completely saturated and the absorbed fluids freely exposed to outside influences. As soon as a wound-dressing has become saturated, or so clogged with wound-discharge that it has lost its original character of an absorbent, discharges are retained in the wound, and so produce all the evil effects of septic or aseptic fluids under tension.

Chemical materials in the substance of the dressings do not favor the absorbing qualities of the dressing, and do not counteract the evil effect of fluids retained under tension. It is, however, a clinical fact that when iodoform gauze is used as a packing, or for drainage in septic wounds, putrefactive changes in the discharges take place less readily than when simple aseptic gauze is employed. Confidence in this preserving quality of iodoform gauze is far less complete now than it was a few years ago, and surgeons are much more frequently making use of plain sterilized gauze for wound-dressings and for drainage, even when discharges are thoroughly septic.

The commercial term for gauze is cheese-cloth, which can be conveniently cut into pieces one yard square, and folded or rolled up, as may be most convenient.

Iodoform gauze is prepared by dipping plain gauze in the following mixture: A half-pound of iodoform powder is mixed with 4 ounces of glycerin. Two liters of thick soap suds and the mixture of iodoform and glycerin are then stirred together. To this mixture are added two liters of carbolic-acid solution of the strength of 1 to 20. The quantity thus prepared is sufficient to impregnate 30 yards of gauze. Plain iodoform gauze may also be prepared in a simple manner by rubbing pure iodoform powder into the meshes of ordinary cheese-cloth, which should, of course, be previously sterilized. Ordinary absorbent cotton is cut for convenience into sheets or squares of various lengths and sizes.

The Sterilization of Dressings.—Gauze and cotton, having been cut and made up into separate bundles, are wrapped up, carefully pinned in towels, and placed in a sterilizer. At the Roosevelt Hospital the sterilizers are provided with metal boxes, which rest on shelves. These boxes are about one foot square and four inches deep. The lid is detachable. One end of the box has a series of openings arranged like the spokes of a wheel. On the outside of the openings is placed a disk revolving on a central pivot. The disk is also provided with openings which correspond with those in the end of the box. A free admission of hot air or steam into the interior of the box thus takes place. If the disk is given a partial revolution, the openings no longer coincide, and the cavity of the box is excluded from communication with the outside air. The lid of the box is so arranged that, when the disk is open, the lid is slightly raised, so that a very free circulation of steam is permitted. When the disk is closed, the cover falls into place and is locked down by the same action.

The box having been lined with a towel, the dressings inserted, and the lid replaced with the disk open, it is put into the sterilizer, and the contents submitted to ten pounds' pressure of live steam for half an hour. The steam is then shut off from the sterilizer and allowed to play without pressure in the jacket for half an hour to dry the dressings. The sterilizing process is repeated on the following day. When the dressings are to be removed,

the sterilizer is opened, and, as each box is taken out, the disk is turned so as to occlude the openings as above mentioned, this action closing the lid firmly and locking it. Iodoform gauze is sterilized and kept best in the following manner: Strips of this material, of a convenient width and length, are put into glass ignition-tubes, the mouths of which are plugged with cotton. These tubes are shaped like test-tubes, about six inches long and one inch in diameter, and are made of heavy glass.

A number of these tubes, firmly packed with iodoform gauze and plugged with cotton, are put in a wire basket which fits the sterilizer, and are then submitted to steam sterilization as already described. Towellings and other loose materials are packed into a large cylindrical basket of wire which fits the sterilizer and is capable of holding a large amount of material.

For transportation about a hospital, the boxes such as described are sufficient. In private practice, a convenient carrier for sterile and iodoform gauze is a large glass tube, a foot long and about 3 inches in diameter. The mouth of this tube should be somewhat contracted, in order that, after it has been packed with gauze, it may be securely closed with a cotton plug. These tubes are convenient for carrying the various kinds of dry dressings which it is desired to keep in a sterile condition. The tubes are packed with such materials as are required, plugged with cotton, sterilized, and not opened until the contents are to be used. If no steam sterilizer is at hand, plain gauze can be safely prepared by a simple boiling process, the solution used being a 1 per cent. solution of ordinary washing soda. The gauze, being wrapped in a towel or put into a bag, is thoroughly boiled for fifteen minutes. When removed from the boiler, it is readily dried by baking in an ordinary oven. Absorbent cotton can be sterilized by being baked in a similar manner without previous boiling. It should not be forgotten that, when these dry materials are to be sterilized in a steam apparatus, they should be previously warmed before the steam is turned on, as cold dressings produce rapid condensation of steam, and thus become unnecessarily wet.

FIG. 57.—Large glass cylinders in which gauze is to be packed and sterilized, the mouth being plugged with cotton. Gauze can in this way be carried about without danger of infection.

Preparation of Rubber Goods.—Articles made of hard rubber cannot be boiled without injury. Pessaries, nozzles of syringes, etc., should be thoroughly washed in soap and warm water, and then preserved in a 1 : 1000 bichlorid-of-mercury solution. Soft rubber materials, such as drainage-tubes, bulb-syringes, etc., are to be boiled in plain water and then preserved in the sublimate solution. What is commonly called "rubber tissue" consists of very thin sheets of gutta-percha, and is used for superficial drainage, for covering skin-grafts or denuded surfaces, and as a covering for outside dressings, to keep them moist. This material should be thoroughly washed in soap and water, rinsed off in fresh water, and preserved in a jar containing a 1 : 1000 bichlorid solution. The water which comes in contact with gutta-percha must not be too hot, as the material is very delicate, and immediately shrivels up under heat. Glass and rubber drainage-tubes should

be washed, boiled for half an hour in the 1 per cent. sodium-carbonate solution, and preserved in jars filled with 1 : 1000 sublimate fluid.

Instruments.—Instruments, with as few exceptions as possible, should be of metal, and it is desirable that they be simple in construction and smooth on the surface, that they may be easily washed and rendered perfectly clean. Screw joints do not meet this indication, and when instruments are made of two parts, such as scissors, the members should be joined by locks or pivots, which will permit them to be readily separated. Immediately after use, instruments should be scrubbed with a brush and thoroughly washed with soap and hot water. They should then be boiled before being placed in the instrument case. Just before operations instruments should be freshly boiled for fifteen minutes in a 1 per cent. solution of sodium carbonate. Soda solution is more serviceable than plain water, for the reason that, in the former, instruments do not rust and sterilization is more perfect. Almost any suitable vessel may be used as a boiler for instruments. It is convenient to have the boiler provided with a wire basket, in which the instruments are placed, and which facilitates their removal; but if wrapped in towels or put into a bag, instruments may be perfectly well sterilized in any boiler, and without apparatus especially designed for the purpose. Care must be taken that during the boiling process no instrument comes directly in contact with the bottom of the boiler. If this accident happens, the instrument is liable to suffer from too high temperature. From the boiler, instruments should be transferred, without handling, to suitable trays containing a sterile 1 per cent. soda solution. As needles and knives are injured by a prolonged process of boiling, these delicate instruments should be subjected to sterilization for only five minutes, a period which is long enough for their complete sterilization. Syringes and aspirators, if made entirely of glass or metal, may be boiled. If they have leather washers they should be taken apart, the glass and metal portions boiled, and the leather parts washed in soap and water and then rinsed thoroughly with alcohol. The parts of these instruments having been put together, the whole apparatus is preserved in a 1 : 40 carbolic-acid solution. The aspirator needles are boiled like other instruments.

For transportation it is convenient to have metal boxes of a suitable size, which can be sterilized, lined with cotton, and filled with instruments. For small instruments, a convenient box is one eight inches long, four inches wide, and one and a half inches deep. The cover is just like the lower part, and the sides of the cover about the same depth as the sides of the bottom part. The cover, being slightly larger, telescopes over the lower portion. The fitting should be accurate, in order that the box may be as nearly air-tight as possible.

The Preparation of the Operator and the Patient.—Fortunately, most of the objects that come in direct contact with wounds made by the surgeon can be rendered perfectly sterile, and not only sterile, but also non-irritating to the tissues. There is no difficulty in having absolutely sterile clothing, sponges, towels, ligatures, sutures, instruments, and other utensils. If these sterile objects are manipulated with a proper regard for aseptic technic, they never in themselves cause disturbance in healing. The real source of infection of a wound

deliberately made by a careful surgeon who uses perfect materials and handles them perfectly is to be sought, with very rare exceptions, either in the skin of the patient or in the hands of those directly concerned in the operation. The skin of the patient and the hands of the surgeon and his assistants, then, deserve the most careful attention possible. The surface of the body is constantly covered with germs and dust, and is also more or less soiled with the various excretions of the body. Unfortunately our most valuable sterilizing agent, heat, is not entirely available in preparing either the patient or the surgeon, and we are forced therefore in such preparation to depend on mechanical and chemical processes. Recognizing, therefore, that our methods are [illegible] we should take the utmost care to apply them [illegible] as far as possible, the special dangers of wound-[illegible] Smooth skin surfaces can be rendered [illegible] but the natural apertures of the [illegible] anus, and natural [illegible] and at the navel [illegible]

[illegible]

and chemical processes, and, on account of the irritating effect of chemical antiseptics, no method can be frequently and continuously applied without causing irritation of the skin. Of the various methods generally in use, there are three that demand special attention, and in all of them, the first and most important step is the complete removal of all soiling by the thorough application of soap, water, and scrubbing brush. Hands and arms should be thoroughly cleansed by using strong alkaline soap, hot water, and scrubbing brushes that have been previously sterilized, in order to obtain, as nearly as possible, an aseptic condition. Scrubbing brushes should be boiled in a 1 per cent. solution of carbonate of soda for five minutes, and then kept in a sterilized fluid. While scrubbing, it is best to keep the hands and arms immersed in hot water, and particular attention should be given to the finger-nails, which should be carefully cleansed with a good instrument. The nails should be neatly and smoothly trimmed, and loose bits of epidermis completely removed. All cuts, cracks, and rings interfere with proper cleansing. Patches of collodion, and minor dressings of a similar character, are not to be tolerated on the hands of the operating surgeon, for they are likely to act as sources of infection to the wound. Collodion is not aseptic.

First Process.—Of the three methods in common use, that of Fürbringer is the most popular. The most objectionable feature of this process is the use of bichlorid of mercury, which not only discolors the hands, but frequently causes eczema, and leaves the skin cracked, hard, and tender, thus forming a favorable medium for the growth of bacteria. Carbolic acid has similar harmful effects. The details of this method are these: 1. Thorough scrubbing of the hands and arms with soft soap and hot water for at least three minutes, special attention being paid to the nails. 2. Immersion of the hands and forearms for one minute in 95 per cent. alcohol, the nails and the fingers being thoroughly rubbed and scrubbed, in order that fats and débris of all kinds may be removed, and the penetration of the bichlorid-of-mercury solution be more direct. 3. Final rinsing of the hands and forearms in a bichlorid-of-mercury solution (1 : 1000), the fluid being well rubbed into the skin.

Second Process.—1. Thorough scrubbing of the hands and forearms, as in the first method described. 2. Soaking in saturated potassium-permanganate solution, at a temperature of 110° F., until the skin acquires a very dark-brown color. 3. Immersion of the hands and forearms in a saturated solution of oxalic acid, at a temperature of 110° F., until the skin has decolorized. Oxalic acid is probably the most active antiseptic agent in this process, the permanganate of potash acting simply as an oxidizing agent. 4. Thorough washing in sterilized normal salt solution or in ordinary sterilized lime water. 5. Washing in bichlorid-of-mercury solution (1 : 1000) for one minute, and then in sterilized normal salt solution.

Third Process.—The recent reports made by Dr. L. A. Stimson in regard to a process which was first suggested by Mr. Rauschenberg, the pharmacist at the New York hospital, have attracted much attention on account of the valuable results obtained clinically. The advantages claimed for this method are superior sterilizing power and

exceptionally perfect removal of dead epithelium, fat, and débris. The process is as follows:

1. Hands and arms to be washed as in the other methods.

2. A scant tablespoonful of chlorinated lime is to be moistened with enough warm water to make a thick paste. This paste is to be applied thoroughly to the hands and arms, and carefully rubbed in about the nails.

3. A piece of carbonate of soda, about an inch square and a half-inch thick, is to be crushed and rubbed into this paste until the latter becomes smooth. A sense of coolness will then be experienced, following the sensation of heat previously caused by the liberation of chlorin gas. From three to five minutes are thus occupied.

4. The hands are now to be rinsed in sterile water and washed in an aqua ammoniæ solution of the strength of $\frac{1}{6}$ of 1 per cent., in order that the odor of chlorin may be removed. If the skin becomes irritated from too frequent use of any one of the above methods, applications of glycerin and rose water in equal parts after operations will relieve the discomfort.

When the surgeon's hands are intelligently and conscientiously cleansed by one of the above-described processes, such a degree of surface-sterility can be obtained that bacteriological tests made immediately after the application of the process furnish, in some instances, 95 per cent. of successes. Such tests may be made by removing scrapings from the surface of the hands, especially about the nails, and placing these scrapings in sterilized culture-media. The culture-tubes are then placed in an incubator kept at a temperature of 80° F. In a few days' time, the appearance or non-appearance of bacterial growth in the tubes will indicate whether the scrapings placed in them were free from germ-life or not. It is evident, of course, that when one is investigating the condition of the entire hand, such a test as this is a very partial one only, not merely with reference to the time of the beginning of an operation, but also having in mind what the condition of the hands shall be in the middle or at the end of the operation; and it is evident from the considerable number of failures to produce even surface-sterilization, such as will bear the application of this very partial test, that absence of sterility of the surgeon's hand is liable to exist at any time. We must remember, too, that in hospital practice, and often in private work, the hands of assistants employed in operations are frequently changing, and that every few months new hands are introduced, the possessors of which have only just begun to learn the method of cleansing them. Some of these hands come in contact with old wounds and with foul discharges, and are necessarily more difficult to sterilize than others. Moreover, it is certain that the handling of infected tissues which accompanies the dressing of any but perfectly aseptic wounds, and the methods of hand-cleansing which roughen or crack the skin, render perfect hand-sterilization excessively difficult or impossible. The hand exfoliates epithelium and excretes from its glandular apparatus effete material. It is quite certain that we shall never be able completely to sterilize all the hands employed in an operation in such a perfect manner that they will remain sterile until the operation is finished, even supposing that they

were in a perfectly sterile condition at its commencement. Such considerations have led some surgeons to look for a material capable of complete and permanent sterilization, and possessing the quality of impenetrability to fluids, with which the hands might be covered, and thus the danger of conveying infection through their medium to wounds be absolutely excluded. The problem has been solved in a most satisfactory manner by the introduction for the surgeon's use of thin, well-fitting india-rubber gloves. These can be sterilized as perfectly as any instrument, for they permit the use of boiling water, or of steam under pressure, and they are impervious to fluids, either from within or from without. It seems, then, that this improved method answers very completely the question in regard to hand-sterilization.

Mikulicz's suggestion that sterilized cotton gloves answer the indication seems hardly worth serious consideration, since, although cotton gloves can be thoroughly sterilized, they are entirely pervious to fluids, and the hands encased in them must, therefore, if not absolutely sterile, be quite capable of conveying infection to the wounds which they are handling. A material pervious to fluid may, of course, filter from that fluid palpable masses of epithelium or other foreign material, but as fluids can pass from the wound through them to the hand, and again return, the fundamental rules of aseptic surgery are hardly complied with when the surgeon uses material of this kind to cover his hands.

India-rubber gloves are readily prepared for use in the following manner: They are first thoroughly washed with soap and hot water, to which a little aqua ammoniæ has been added. They should then be boiled for fifteen minutes in a 1 per cent. soda solution. Being carefully removed by means of sterile forceps, they should be laid in the center of a freshly sterilized towel, which is then to be folded over them. Operator, assistants, and nurses should put on fresh gloves for each operation. If the hands are quite dry and are then well rubbed with sterilized starch powder, or, indeed, with any finely divided powder, the gloves can be quite easily drawn on, even when their interior is moist. The hands may also be moistened with glycerin, or with any other lubricating material which does not contain oil; the wet gloves can then be easily put on. Oily lubricants are damaging to india-rubber. When filled with any sterile fluid, the gloves permit the hands to enter readily. If this last method is made use of, the hands should be first sterilized as completely as possible, as the fluid which fills the gloves flows out and over its outer surface as the hand enters. After the gloves have been put on, their outer surface should, as a final precaution, be carefully rinsed off with sterilized salt solution. The hand is then in a condition of such perfect sterilization that, gloved in this manner, it may enter and handle aseptic tissues without the slightest danger of causing infection.

In active military and naval service, india-rubber gloves would be of the greatest value. When rolled up they occupy a very small compass, can be transported in a sterilized condition, and can be readily sterilized over and over again in any small vessel which can serve as a boiler. The best methods of sterilizing the hands would be totally impracticable in a rapidly-filling army hospital, but, provided with a few pairs of gloves, an army or navy surgeon need never dread causing infection through his hands to the wounds which he makes. At the Roosevelt Hospital rubber gloves have been in constant use for over

a year, and the clinical results in aseptic surgery are much better than have ever been attained in that institution before.

After a little practice, any operation can be done as well with rubber gloves as without them; nor do the gloves interfere in the least with accurate palpation. When tissue, such as a portion of intestine, is very slippery, the difficulty is overcome at once by the aid of a piece of sterile gauze. If thick pedicles have to be tied with force, a piece of gauze in the palm of the hand prevents the ligature from cutting the glove. If the glove finger is accidentally cut or pricked, the wound may be at once closed by putting over it an extra glove-finger. Perforations of small size may also be very perfectly mended by means of a rubber cement furnished for that purpose. A pair of gloves handled with care will last from four to six weeks, even when used every day.

Preparation of the Patient.—At least once before operation, if no contraindication exists, the patient should be given a thorough hot bath with abundant application of soap, after which only fresh clothing should be worn. Generally, a suitable laxative should be administered on the day before operation, and, on the morning of operation, an ordinary soap-and-water enema should be given, so that the bowels may be properly freed from accumulations. No food of any kind should be taken within six or eight hours of the time for the administration of the anesthetic, excepting that a few tablespoonfuls of coffee or a small cup of hot broth may be given in the early morning. Stimulation, if indicated, should be given through the rectum. The preliminary preparation of the *field of operation* should be made in the following manner: The area cleansed should always be much larger in any case than the part to be immediately involved in the wound. This is absolutely essential, because towels about the immediate operative field become easily displaced, thereby often exposing unprepared surfaces, unless sterilization is carried wide of the actual operative wound. Generally, on the night before, the skin should be carefully shaved, if hairy, and then thoroughly scrubbed with good soap, hot water, and a sterilized brush, in order that all soiling and loose epidermis may be removed, and special care should be taken with irregularities of surface, such as the navel. All soapy material should be then washed away.

In the preparation of callous or very dirty integument, such as that of the hands and feet, sterilization should begin two days beforehand, the washing process being repeated twice daily, and the parts continuously enveloped in a soap poultice between the baths. In all cases, for at least six or eight hours before an operation, the whole operative field and its neighborhood should be covered with a soap poultice. This poultice is made by taking several thicknesses of gauze and soaking them in a quantity of soft soap suds of a moderately thick consistence. The water contained in the poultice may then be gently squeezed out and the gauze applied to the skin. During the process of sterilization, the hand of the person employed should be in a sterile condition. When the patient reaches the operating table, the poultice is to be removed, the surface washed off and thoroughly rinsed with hot water. The parts should then be rubbed with alcohol, so as to secure the complete removal of all fatty substances and other débris, and finally the

entire area should be washed with a solution of bichlorid of mercury (1 : 1000), or, better still, pure sulphuric ether. One should be careful, however, and see that under no circumstances is the skin excoriated by too rough scrubbing or by the too free use of chemical applications. Lastly, ulcerated surfaces in or near the immediate operative field should generally be cauterized with the Paquelin cautery. As soon as the operative field and its surrounding surface have been thus prepared, the whole region should be immediately covered with wet sterilized towels, so as to exclude the possibility of accidental surface-infection. The entire body, excepting such space as is required for operation, should be properly protected with warm coverings, and the lower extremities may be advantageously enclosed in leggings. Rubber sheetings placed over the blankets or other coverings prevent the latter from becoming soaked with the fluids used, and over these are to be spread sterilized towels which have been wrung out in a sterilized salt solution. During the operation these protecting towels should be frequently changed, as they become soiled with blood or other materials. The scalp should be covered with a rubber cap, over which should be wrapped a wet sterile towel; and the ether cone should be protected with towels as well. Wet towellings have a great advantage over dry ones, since, when once placed, they do not slip, and dust, which necessarily falls upon them, is detained on the wet surface. If these directions are carefully followed, every part of the patient excepting his face, and every part of the table and of the unsterilized coverings over the patient, will be separated from the surgeon, his assistants, and the operative field by sterilized material.

Every portion of the body which is to be operated upon should be prepared for operation in as sterile a manner as is consistent with the peculiarities of the region. If an operation that involves *the mouth* is to be done, the whole cavity of the mouth, the teeth, and the pharynx should be sterilized as completely as possible. Loose or decayed teeth should generally be removed. The teeth themselves should be frequently brushed with tooth powder, all tartar scraped away, and the mouth and pharynx rinsed and gargled at frequent intervals with suitable cleansing material. For this purpose, peroxid of hydrogen, one part in five or six, is the best. Similar methods are to be applied to the cavities of *the nose*, to the postnasal region, to the ears and aural canal, when any one of these regions is to be included in the operative field. The removal of adenoid vegetations from the nasopharynx, of polypi from the nose or aural canal, and all similar operations, should never be undertaken without careful preliminary preparation of the parts. The failure to observe this rule has often resulted in sepsis of a grave character. The skin of *the eyelids* and the conjunctiva itself should be thoroughly cleansed before an operation which involves these or surrounding parts, no matter how slight the operation. For mechanical cleansing of the conjunctiva, sterile normal salt solution is admirable, as is also a warm weak solution of boric acid. If the cavity of *the cranium* is to be entered, shaving of the entire head is never to be neglected. Not infrequently the scalp, particularly when the hair has been long and neglected, is covered with dense masses of old epidermis and dried discharges from eczema. In such cases, simply

washing with soap and water, or even the application of a soap poultice for the usual length of time, will not be sufficient, and to cleanse the scalp thoroughly it will be necessary first to soften completely the whole surface with applications of sweet oil kept upon the scalp for one or two days preceding the final washing. If sufficient trouble is taken, and the hair cleanly shaved, it is possible to render the scalp as clean as any other part of the body.

When operations are to be done upon *the stomach*, or the intestine immediately below the stomach, it is best to precede the operation by a thorough lavage. The fluid used may be either warm water, boric-acid solution, or the normal salt solution. By this means the stomach can be rendered absolutely clean.

Even in operations on *the pharynx* and upper air-passages, the risk of infection through the vomiting accompanying or following etherization can be largely diminished by lavage of the stomach beforehand.

Operations upon any portion of the *intestinal tract* should be preceded, whenever it is possible, by satisfactory emptying of the whole intestinal canal by means of suitable laxatives. In addition to medication, enemata can be used with great advantage whenever operations are to be done upon the lower bowel. A thorough cleansing of the rectum and anus permits most operations involving this region to be practised in a nearly aseptic manner. It is hardly necessary to mention that, in all operations upon the intestines and gall-bladder, every care should be taken to prevent the entrance of intestinal contents into the peritoneal cavity or upon surrounding coils of gut. The portion of intestine to be operated upon can frequently be brought entirely out through the abdominal wound, and so the whole operation be made extraperitoneal, or, at least, the intestine may be clamped or tied above and below the part to be opened or operated upon, and so the passage of fecal material by the seat of operation be avoided.

Operations upon the *bladder and urethra* require for their safe performance very complete cleansing of these organs. The bladder should be emptied completely, by means of a catheter, at the last moment before operation. It should then be filled and emptied several times with some sterile fluid, normal salt solution, or Thiersch's solution. Ordinarily, at the moment of an operation it should be full of a sterile fluid. The urethra also should be carefully washed out in a similar manner. These precautions should be taken in any case of actual operation for the relief of stricture, and at least after any discharge [illegible] the urethra should be washed before even a sound is introduced. [illegible]

in a 1 per cent. solution of sodium carbonate heated nearly to the boiling point, the instruments will not be injured, and will be well sterilized. Catheters should be preserved in a solution of bichlorid (1 : 1000), all traces of which solution should, however, be washed away with hot water before the instrument enters the urethra. The interior of catheters can best be cleansed by the passage through them of boiling water or live steam.

The vagina, as well as the external genitals of the female, deserve especial attention in all operations which involve them; and they should not be neglected when operation is to be done upon the anus or lower rectum. To cleanse the vagina thoroughly a speculum is necessary, so that it may be held widely open while every portion of it is wiped out with a sponge on a long handle, and vigorous applications of Thiersch's solution should be made. If the interior of the uterus, or even the cervix, is to be entered with an instrument, these tracts should be prepared as carefully as the vagina, and, in many cases, the orifice of the cervix and its canal require careful curetting.

Accident Wounds.—A large proportion of accident wounds, such as small lacerations, scalp wounds, gunshot wounds, and even compound fractures, are originally nearly aseptic, and remain so until they have been handled or otherwise actively disturbed. Such wounds frequently first receive officious and unskilful attention from those who make no pretence at cleanliness, and, by the time they come under the hand of the surgeon, are already infected. The application of septic temporary hemostatic apparatus or drugs, ordinary materials used as dressings, ignorant probing, and handling with dirty fingers and instruments, more frequently infect these wounds than does the agent of the traumatism. The surgeon should therefore treat all accident wounds with especial care, realizing that they will frequently have been infected through the hands of some other person before they reach him. Moreover, such wounds are frequently irregular in outline and complicated by lacerated and contused edges. If, in any case, it seems best to close such a wound by suture, it should first be very carefully disinfected. If doubt exists in the mind of the surgeon as to the thorough disinfection of such wound, it is far better to leave the wound open, packed with suitable material for drainage, than it is to apply a suture. For the temporary control of hemorrhage from any but large vessels in accident wounds, nothing is better or safer than compression exerted by means of sterilized gauze, which fills the wound and is held in place by a sterile bandage. The final dressing of all accident wounds should include very thorough cleansing of the skin of the entire neighborhood about the wound. The wound itself should be washed thoroughly with a non-irritating fluid, such as normal salt solution or Thiersch's solution. It should then be dried by the use of sterilized gauze. Ragged edges which are evidently beyond recovery should be cut away, undermined edges lifted, and the underlying spaces sterilized. Whether such wounds may be closed by suture or not must, of course, be decided according to the judgment of the surgeon in charge. As a rule, provision for some drainage should be made, and for this purpose capillary drainage obtained by means of gauze packings is better than any arrangement of drainage-tubes. Exten-

sive, deep, lacerated wounds should under no circumstances be closed primarily, and in a very large majority of cases secondary suture is far safer than primary closure. Such secondary suture may be well applied often on the second or third day, the absence of infection being by that time determined.

Wound-suture and Drainage.—Before operation wounds are sutured, they should be carefully washed out with hot salt solution, so that all blood-clots may be removed. All oozing points should be carefully ligated, preferably with fine catgut, and all hanging fragments that are liable to necrosis should be cut away. If a wound is to be completely closed, the surgeon should endeavor, by means of properly applied sutures, to bring all raw surfaces in contact with the opposite ones, and, so far as possible, he should so arrange the deep and superficial tissues that no dead spaces are left in which serum and blood may accumulate. For buried sutures, as has been already stated, catgut is to be preferred to any other material. It is true, however, that many surgeons make free use of silk, silkworm-gut, and even silver wire, the objection to these three materials being, in the opinion of the writer, a grave one—namely, their non-absorbability. The different layers of tissue in wounds should, as far as possible, be sutured to corresponding layers on the opposite side. In some cases, where haste is required, it is permissible to pass sutures from the surface through the entire thickness of a flap, even when it is composed of a number of different layers, omitting entirely, in order to save time, special suturing of separate tissues. This method of suture, however, is not likely to yield as perfect a cicatrix through the whole surface of the wound as the separate suture of tissue to tissue. It is better to avoid placing a suture than to place it where great tension will be caused by drawing wound-edges together, for continued tension will produce either necrosis from complete shutting off of blood-supply, or tissue-absorption, which again may invite the development and multiplication of otherwise harmless bacteria. Skin-edges should be well supported in all large wounds by a number of sutures of fairly large size which pass through the skin at points $\frac{1}{4}$ or $\frac{1}{2}$ inch distant from the edge of the wound. These sutures may be placed from 1 to 2 inches apart. The immediate suture of the edges of the wound should be as complete as possible and safe. It may be made either with fine catgut or with fine silk, the writer preferring the latter material for skin-sutures. Fine silk is stronger than catgut of a corresponding size; it is more pliable, and it leaves a neater cicatrix. For the strong supporting sutures, many surgeons prefer silkworm-gut or silver wire, and for the final immediate skin-suture, some use a buried fine silk strand, which does not pass through the skin at all, but catches up only the immediate subcutaneous edge. Theoretically, a perfectly aseptic wound may be completely closed without drainage of any kind, and this practice may in many instances be followed by complete success. It can be accomplished uniformly, however, only at the expense of a large amount of time devoted to the permanent checking of all hemorrhage, however slight, and by very complete and time-consuming attention to the obliteration of all dead spaces. All wounded tissues exude a certain amount of serum, and there are few wounds, no matter how

carefully attended to, which are not followed by more or less subcutaneous bloody oozing. In a small proportion of cases, which at the time of closure seem to be absolutely free from bleeding, one or more vessels will, after closure, allow of a considerable hemorrhage into the tissues. The presence of pure serum or blood-clot in the cellular spaces of a wound is certainly an invitation to bacterial development which, in a perfectly empty wound, would not take place. Whether it is worth while to accept even a small risk of such accident for the sake of completely closing the wound in an ideal manner must be left to the judgment of each surgeon. Carefully applied drainage, in one form or another, provides against accumulations of serum, accidental bleeding into the tissues, and reduces to a minimum the chance of bacterial invasion. The writer therefore prefers to give up the ideal closure of wounds without drainage of any kind, and so avoid much loss of time and some risk to the patient. Drainage, therefore, should be applied to almost all wounds, even those which are presumably perfectly aseptic, in order to remove from the intercellular planes such serous or bloody exudations as are certain to exist to a greater or less degree. In aseptic wounds, drainage for the purpose above mentioned will have accomplished its object within a very few hours, and should be removed at the first convenient opportunity. This is generally done at the first change of dressings. Such change might well be made on the next day after operation, if it were not that a disturbance of dressings at so early a period is generally very uncomfortable for the patient. As a rule, therefore, this temporary drainage-material is most conveniently taken away at the end of about forty-eight hours. All superficial aseptic wounds, and even many large and deep ones, may be perfectly drained if the surgeon introduces at one or two points a narrow strip of thin gutta-percha tissue, which should pass from the surface to the deepest portion of the wound that requires emptying. Such strips can be readily placed by means of a probe. They should be from $\frac{1}{4}$ of an inch to $\frac{1}{2}$ inch wide, and should project above the surface for about an inch. Serum or fluid blood will find its way by the side of such drainage-material into the superficial wound-dressing, so that, when the first change of dressings is made, this material will be found always to contain a considerable quantity of fluid, and the wound will be satisfactorily flat and free from all accumulations. Moreover, these strips of thin gutta-percha never leave behind them a prolonged sinus, even when left in place for a considerable length of time, and the wounds to which they are applied heal with great rapidity. Where, however, a considerable opportunity exists, as in the axilla after its complete excavation, for the accumulation of bloody fluid, it is safer to introduce a drainage-tube at a conveniently dependent point. Such a drainage tube, if left too long in place, is likely to give rise to the existence of a sinus which may last for some little time. If the tube is removed, however, on the second or third day, the place which it occupied invariably heals without difficulty. For tube-drainage, india-rubber is usually the most convenient, but, instead of india-rubber, tubes may be made of absorbable bone, of glass, or of metal. India-rubber tubes, from their pliability, are to be preferred in ordinary wounds. Wherever there is a liability to com-

pression of the tube to such an extent as to occlude its caliber, glass is the most suitable material. Especially is this true where the pelvis requires drainage from the bottom of this cavity to the abdominal wall. Ordinarily, cavities requiring drainage, which are very irregular in shape, or have collapsible walls, such as are formed by coils of intestine, may be more perfectly kept empty by capillary-drainage, such as is furnished by gauze packings, than by tubes. A combination of capillary- and tube-drainage is occasionally very valuable. Such combination, and, indeed, capillary-drainage in general, is only required in septic wounds, or in those which, from their nature, are liable to become septic.

In cases of septic peritonitis, the abdominal cavity having been found to contain a quantity of turbid fluid, extensive washings with sterile salt solution, at a temperature of from 110° to 120° F., are first made use of. Such washing is capable of cleansing the peritoneal cavity to such an extent that it is nearly aseptic, but, of course, all of the washing fluid is never removed; and yet it is desirable that the peritoneal cavity should be completely emptied as soon as possible. The remnants of irrigating material, and also the fresh exudations of serum, are likely to find their way into the pelvis, and can be best drained from this cavity by means of a large glass tube. This should be from ¼ to ¾ of an inch in diameter, open at both ends, and long enough to extend from the bottom of the pelvis to the surface of the abdominal wall. The lower third of the tube should be pierced with small holes in the sides, so as to offer a greater opportunity for the escape of fluid from the pelvis into the cavity of the tube. A piece of gauze which passes to the bottom of the tube should be left in that situation, and this will, by capillary-drainage, convey much of the fluid to the surface. After operation, however, this gauze should be removed every four or six hours for a day or two, so that the interior of the tube may be kept reasonably empty. Even in such cases, if the operation has been well managed and the washings made complete, the wound is at once brought to a very perfect condition, and the tubes, if found to contain perfectly clean serum only, may be safely removed at the end of forty-eight hours. In other parts of the abdomen these large glass tubes may be frequently used to great advantage.

It should be the object of the surgeon in handling septic wounds to bring them as rapidly as possible to a clean condition. This can be accomplished with certainty only by the most perfect and constant removal by drainage of all septic exudation and accumulation. For this purpose, capillary-drainage is far superior to any other method, and [illegible]

Post-operative Treatment of Wounds. [illegible]

they are septic or aseptic, deserves a close attention to detail. Wounds are rarely infected, if only reasonable care is taken, at the time of the change of dressings. Nevertheless, it is quite possible at this time by carelessness to introduce infection, either through the agency of soiled fingers, imperfect dressing-material, imperfectly sterilized instruments, or by contact with bedding and underclothing. If the condition of the hands employed in making a dressing is doubtful, sterilized india-rubber gloves should be worn, and it is very desirable that the dresser and person assisting him should carefully avoid carrying infection from a septic case to a clean one. Before the wound is exposed, and before the deeper dressing is removed, the bedding and underclothing should be excluded from contact with the wound by covering them with sterilized towels or rubber sheeting. The patient's hands should be placed where they may do no harm. The instruments to be used should have been just sterilized, and all the dressing-material should be in a perfect condition. Implements of all kinds, such as bowls, irrigators, syringes, etc., which are to be used in connection with the dressing, should, of course, be absolutely free from infection. The dressing may now be removed, the wound properly attended to, such sutures as have served their purpose removed, and all skin in the immediate neighborhood of the wound-surface thoroughly cleansed. For this purpose hydrogen peroxid is admirable. The wound should, of course, be carefully inspected with a view to the possibility of infection, and if any signs of this accident present themselves, the suspected portion of wound, or even the whole of it, should at once be laid open, and treated according to the condition found. As a rule, aseptic wounds which have been very completely closed require a change of dressings at the end of forty-eight hours, in order that all material soiled with discharge of blood or serum may be removed, as well as drainage-material. Frequently, at this time, heavy supporting stitches may be advantageously cut. Where there is tension, it is often better to let these last-mentioned stitches remain in place for a few days longer. The suture at the edge of the skin need not be disturbed ordinarily before the seventh or eighth day. In the dressing of such open wounds as have been freely packed, irrigation is comparatively seldom of value. Dry cleansing of the wound—that is, the absorbing of all fluids by means of sterilized gauze or cotton—is generally to be preferred to irrigation with fluid. In any case, all irritating fluids, which by their caustic effects might interfere with the production of granulation-tissue, are to be avoided. If a fluid is required for mechanical cleansing, the safest material is normal salt solution. Unless actual sloughs exist, solutions of carbolic acid and bichlorid of mercury are rarely desirable. Actually dead material had better be removed with scissors at once. A dressing similar to that applied at the time of operation is then to be carefully replaced. It is a mistake to suppose that because a wound has become infected, and is already discharging septic material, it cannot therefore be injured by soiled hands and by the use of infected materials. No wounds require greater care than open septic ones, and if the surgeon desires, as he must, to bring them as rapidly as possible to a condition nearly approaching asepsis, he must treat them with as great attention to aseptic detail as is possible under the circumstances.

The Operation.—The manner in which the various items of the aseptic surgeon's paraphernalia must be prepared has now been given in detail, and it only remains to consider how they may be brought together and utilized, so as to be effective in producing an aseptic result. Proper preparations for the aseptic operation are absolutely essential, and scarcely less important are the system and manner of making use of the articles prepared. Carelessness in regard to the latter point may entirely destroy the value of the former, for in the course of an operation a single neglect of the clearly defined rules of aseptic manipulation may render valueless all the precautions that were previously, and are subsequently, observed. The one general rule must be that no object, be it hand, arm, instrument, sponge, or ligature, which is to come in contact with the field of operation, shall, even on a single occasion, touch any other object which is not positively known to be in a sterilized condition. To observe this rule requires only conviction on the part of every person concerned in regard to its importance, for if the conviction exists, habit of observing it is rapidly acquired.

It is convenient to begin with an operation done in an ordinary house, where previously no special arrangements suitable for operation have existed. The room selected, if the operation is to be done by daylight, should, if possible, be one well lighted by at least two windows on the north side, as direct sunlight is dazzling and confusing. It is convenient to arrange, if possible, that the room selected for operations shall communicate immediately with another room, in which the patient may be anesthetized, and, if possible, a bath-room with hot and cold water should be close at hand. Formerly, it was considered necessary that the operating room should be made entirely bare of furniture, hangings, pictures, carpets, etc. Of course, when such preparation of a room was made, it was necessary to begin the preparations at least two days beforehand. After the room had been completely stripped of furniture, it was dusted and washed, and all the woodwork rubbed with swabs wet in a carbolic-acid solution. Even the floor was treated in the same manner. These preparations were required on the theory that ordinary dust was a very important carrier of infection to wounds, and that not only must every particle of dust be removed from a room, but every object, as well, which might serve as a resting-place for dust settling at a later period from the atmosphere. It is generally acknowledged now that too much regard has been paid to the element of dust, and that while it was very desirable that operations should be conducted in a clean atmosphere, dust which is at rest on objects in a room, and which is not disturbed in the course of an operation, is not liable to do injury. All unnecessary furniture had better be removed, as it obstructs walking space, and is likely to be touched or moved during the operative work. Loose hangings which obstruct light, and which have the same objection that unnecessary furniture has, should also be taken down. Carpets and rugs may be left in place, provided only that they are covered with clean linen or cotton in such a manner that any dust which lies upon them shall not arise into the air. Any piece of furniture which remains in a room, and which is likely to harbor loose dust, should also be properly covered.

The operating table may be of the simplest possible description. An ordinary wooden table, 5½ to 6 feet long, of a convenient height, and with strong legs, is quite suitable. This should be well covered, first with blankets for comfort, then with rubber sheeting to prevent wetting, and finally, over all, with a perfectly clean linen or cotton sheet. Other tables, two or three in number, covered also with clean, freshly laundered material, are required for bowls and pitchers, instruments, sponges, etc. Before the instrument trays and bowls for sponges have been arranged upon the tables, the latter should be finally covered with sterilized wet towels. These tables should be placed in convenient relationship to the operating table, and be so placed about it that articles upon them can be readily reached, and yet so that they shall not interfere with freedom of motion or with the entrance of light. A good supply of sterile water must be at hand, and this can be prepared in the kitchen or laundry by boiling ordinary water in a clean boiler, which is to be brought to the operating room long enough beforehand to permit it to cool off to a reasonable temperature. It is convenient, also, to have a supply of cold sterile water, which can be prepared some hours before the operation by boiling, or can be readily purchased in the form of distilled water, a good sample of it being known as Hygeia Water. Of course, neither hot nor cold sterile water should be exposed to settling dust until the time for operation arrives. In private houses, wet sterilized towels are readily prepared by boiling a desired number for a half-hour in a 1 per cent. sodium-carbonate solution. Before boiling, these towels had better be thrust into a cotton bag or wrapped in a clean sheet, so that the whole bundle may be boiled at once and easily lifted out in a mass. From the enveloping sheeting they may be dropped into a previously sterilized bowl, from which they may be taken with gloved hands or with a clean pair of forceps, one at a time, as required. The patient should be anesthetized in a separate room, in order that the operating room may be entirely at the disposal of nurses and assistants up to the time of operation. It is undesirable, also, that the patient should see the preparations that have been made. The general look of an operating room has upon some patients a very undesirable effect. The patient is now to be carried to the operating room on a suitable stretcher, hands and arms alone not being satisfactory for this purpose.

A portable stretcher for use in private houses has been devised by the writer. It consists of two very light six-and-a-half foot tubular rods of aluminum. These are hinged in the middle, so that the length of the stretcher may be diminished by one-half for convenience in carrying. When at full length, the tubular rods are fastened together by a transverse one at either end, these transverse rods being movable. The bed of the stretcher is formed by a strong piece of canvas. The whole apparatus can be folded in the middle and then rolled up, so as to make a small and light bundle.

The patient having been put upon the operating table, and all parts that do not have to be exposed being warmly covered, thin rubber sheetings should be spread over all excepting the operative field. These, of course, are so arranged as to prevent unnecessary wetting. Over these rubber sheetings, numerous wet sterilized towels should be so arranged that nothing but the operative field remains exposed. If any position other than the dorsal recumbent one is desired, it can

readily be secured by lifting the head or foot of the table as required, or by the use of a number of pillows suitably covered. The final sterilization of the operative field should now be made, and, last of all, every hand that is to be employed must be surgically clean. In this connection, the value of rubber gloves may be again referred to, for a pair which has been employed in the final arrangement of the patient and his clothing may now be replaced by one that is absolutely sterile. Each individual should have his special duties assigned to him, for without system and order in manipulation, it is impossible to preserve the rules of asepsis. Especially in private work, the fewer hands that are allowed to come in direct or indirect contact with the wound, the less likelihood is there that the aseptic technic will be broken.

The instrument table should have upon it suitable trays containing a 1 per cent. solution of sodium carbonate, properly sterilized by boiling, in which the instruments may lie immersed. Every instrument that is at all likely to be needed should be ready for instant use, so that there may be no sudden opening of any unsterilized packages, a performance which always ends in confusion. Upon the same table should be trays containing the ligatures that are to be used, which had best lie in pure alcohol. The sponges and pads should be upon a separate table, either in sterilized bowls or wrapped in wet sterile towels. At least two bowls should contain several quarts of hot sterile water, or, better still, hot normal salt solution. Several pitchers of the same fluid should also be at hand.

When operations are to be done about the face and neck, the scalp, including all the hair, should be protected from wetting by means of a rubber cap, which also prevents long hair from getting into the field of operation. This rubber cap should be carefully covered with a sterile towel as an additional precaution against infection.

If the peritoneal region is the seat of operation, the legs and feet also should be covered with sterile towels, as these parts are likely to come in contact with the operator. Similar care should be taken, of course, when other regions are to be operated upon, and especially must the position of the patient not be changed without due precautions in regard to the uncovering of unsterilized parts. Incisions should be clean cut, and should be made with reference to the anatomical arrangements of the parts, bearing in mind the function of the adjacent muscles and joints and also the desirability of avoiding undue tension when the time comes for suturing the wound-edges. Dissections should be made, as a rule, with sharp knives and scissors, and not with blunt instruments and fingers. The more delicately and anatomically tissues are divided and separated, the less likely is necrosis of tissue-fragments to follow, and the fewer will be the unmanageable dead spaces and displaced muscular planes. Gentle hemorrhage should be carefully attended to as the operation proceeds, first, in order that as little blood as possible may be lost, for great loss of blood is a decided invitation to sepsis, and, secondly, that each succeeding step in the operation may not be rendered more difficult by the oozing caused by the preceding one. Not only is the wound itself to be kept constantly free from fluid and clotted blood, but the hands of the operator and assistants should be frequently washed off in a sterile solution. Instruments, also, which are being

used should be frequently washed and kept clean. It is often desirable, during the progress of the operation, completely to clear away fluid and clotted blood. This can be done with sponges, and also by liberally pouring into the wound hot normal salt solution. This preparation clears away blood very thoroughly and does not irritate the most delicate tissue. It is desirable, in short, that the surface of the wound, the hands, the instruments, and even the surrounding skin, should be kept as clean as possible—that is, free from fluid and dried blood—throughout the whole course of the operation. The sterilized towels—which from time to time become soiled—should be constantly replaced or covered by fresh ones. A final cleansing of the wound is to be made just before the suture is applied. Buried sutures of catgut, preferred because of their absorbability, should be applied to replace divided tissues, as far as possible, in their normal position, but this rule should not tempt the surgeon to subject the parts sutured to too great tension. The points where drainage will be most efficient or important will rapidly define themselves. Small and superficial spaces can generally be quite satisfactorily drained with strips of thin gutta-percha tissue. Large spaces that are specially liable to bloody accumulations had better be drained by a tube, and wounds which cannot be properly closed at all, or only in part, are drained in a perfect manner by means of greater or less quantities of sterilized gauze. All wounds should have an abundant dressing placed over them, the deepest portion of which should consist of masses of sterilized gauze, thoroughly covered with sterile absorbent cotton. These thick masses of external dressing keep underlying flaps in place, close empty spaces by pressure, prevent oozing, and protect against external injury. Over the dressing, binders or bandages are to be firmly applied, in order that the parts that have been operated upon may have as complete rest as possible. When the limbs have been operated upon, splints placed over the outer dressings are often very valuable. After the wound has been closed and properly dressed, the patient should be carefully removed from the table to his bed, wet clothing removed, and dry blankets wrapped about him. If stimulation seems required, it may be given at once by the rectum, and a hypodermic injection of morphin is often also found very desirable. External heat applied by means of hot-water bottles is to be carefully avoided. In the first place, many serious accidents by burning with hot-water bottles, while patients have been unconscious from the continued effects of the anesthetic, have occurred; and in the second place, there is no evidence whatever that external heat applied in this manner ever did any good. Should the patient be sufficiently anemic from loss of blood to suggest the necessity for a rapid application of heat, all the indications can be best met by an immediate infusion of hot salt solution into a vein. The first dressing of the aseptically-made wound is to be undertaken according to different indications. Oozing of blood to such a degree as to stain the dressings through at any point calls for an immediate change of dressing-materials. As a rule, the first change of dressings is to be made on purpose that drainage-materials may be taken away, as they will rarely be required after the lapse of a few hours; but since it is often uncomfortable for a patient to have his dressings disturbed on the day following operation, this first

dressing may be conveniently made on the second day. Of course, in many cases, as in resections of joints, it is desirable to avoid any handling of the parts involved, and in such cases the dressings are often left undisturbed for a period varying from one to two weeks, especially when they are covered with plaster of Paris or other fixed material.

Wounds which the surgeon expects to treat in the manner just referred to—that is, with an occlusion dressing which will probably not be disturbed for a prolonged period—should be closed with catgut sutures, and even the bone suture, as in case of resection at the knee, should be of heavy catgut. In other words, a foreign material left in the wound should, if possible, be absorbable. Even drainage-tubes should be made of decalcified bone. It is often more convenient, however, and amply sufficient to use as drainage-material strips of thin gutta-percha tissue, such as have already been referred to. These may be left undisturbed in a wound for several weeks without causing injury, and, when finally removed, they leave no sinus behind them, or, at least, the narrow track which contains such strips heals with the greatest facility.

The details to be observed in making changes of dressings have already been described. Signs indicating that infection of the wound has occurred would, of course, suggest its immediate inspection, in order that such steps may be taken as the character and extent of infection may indicate. The fact, however, that some fever is noted on the day after operation is by no means a reliable indication that infection has happened, for most patients within twenty-four or thirty-six hours after operations have some rise of temperature due to the rapid absorption of wound-fluids, although these are perfectly aseptic. The general appearance of the patient, the character of his pulse, and the character and extent of his wound-pain will usually enable one to decide whether a moderately febrile condition, within a day or two after operation, indicates wound-sepsis or not. If on removal of the first dressing it is found that infection of a wound is present, sutures should be at once divided, the wound opened to as great an extent as seems called for, thoroughly cleansed, and widely drained by complete packings with gauze. If at the first dressing the wound is found to be in an aseptic condition, drainage-material is to be removed, such sutures as are no longer necessary cut, and a fresh dressing applied, which need not again be disturbed until the time comes for the further removal of sutures.

If at the first dressing or at any subsequent period the wound is found to have become infected, the attention of the surgeon should be at once directed to bringing it, as soon as possible, to a perfectly clean condition. Small drainage-openings made at one or two points through the suture-line are rarely anything but disappointments. A small opening made into a more or less widely-suppurating tract relieves tension but very slightly, and almost never permits the wound to become free from infection. As a rule, to which of course there are some exceptions on account of special reasons, infected areas are to be very widely opened as soon as their existence is suspected. By far the most important point in their treatment is the complete relief of tension.

Following this step, provision should be made for the most rapid possible removal by drainage—capillary-drainage by gauze packings is the best—of every drop of unhealthy discharge from the infected surface of the wound. When an actively-secreting wound is packed with dry gauze, the secretions are at once absorbed by the fiber of this material. This process will go on in each instance with perfection and rapidity until the packing has become saturated and can absorb no more, or until its outer surface has become partially dried, and so the process of absorption is interfered with. The moment the secretions cease to be removed from the wound-surface with rapidity and completeness, the wound begins to suffer, and often, too, the individual; and if examined at such a time, all processes of repair will be seen to have become much less active than they were. It is evident, therefore, that drainage-material which has been packed into a wound should be replaced by fresh gauze as soon as it has become saturated, or before that moment, if one would have the wound rapidly brought to a state of perfection. Infected wounds which have been treated by gauze-drainage should have their dressings changed more or less frequently, according to the amount of discharge. After a wound has been opened on account of acute infection, and before it is packed, mechanical cleansing of some sort should be adopted, all discharges should be wiped away, loose sloughs and necrotic tissue removed with the scissors, and general cleansing of every portion of the wound be made with some suitable solution.

Formerly, dependence was largely placed at this stage in wound-treatment upon the vigorous use of chemical antiseptics, such as carbolic-acid and bichlorid-of-mercury solutions. It is doubtful whether preparations of this character have any especial value when applied to acutely infected wounds. While they mechanically cleanse by washing away secretions, just as any other solution would do, they certainly cause some necrosis of granulating tissue, and to that extent interfere with natural processes of repair. Neither is it possible by the use of such antiseptic fluids completely to destroy infection after it has once occurred. Normal salt solution used as a douche cleanses the wound-surface and washes away secretions without having any harmful effect. Such a mechanical cleansing may be followed by the free application of hydrogen peroxid, which by chemical combination breaks up and destroys such portions of the secretions as have not been already washed away. The wound is thus brought into as clean a condition as is possible under the circumstances, and is then to be packed thoroughly, although not tightly, with iodoform or plain sterilized gauze, as the surgeon may prefer. If carefully attended to and often enough dressed, infected wounds are frequently rendered so clean and so free from discharge within a brief period, that their edges may safely be brought together by compression and allowed to unite. If the surgeon operates and dresses his wound with naked hands, he should be especially careful in regard to cleansing his hands *immediately* after the operation or dressing, for blood-stains and infectious material cling to the skin with great tenacity after they have once become dry. A few drops of aqua ammoniæ added to the water in which the hands are washed renders the removal of blood and other discharges extremely

easy. A great advantage attaching to the use of rubber gloves in operations is that the character of one operation or dressing has no influence in determining the success or failure of the next one.

Operating Rooms and Furniture.—Rooms such as are found in hospitals, which are especially constructed and arranged for that purpose, may be divided into two classes—those which are intended for operations without spectators, and larger operating rooms or operating theaters, which are especially arranged for the purposes of demonstration. In both instances the essential features are suitable light, perfect cleanliness, and convenience of arrangements. Direct sunlight is dazzling, and therefore objectionable. A clear north light is best, and this should be supplemented by abundant light from overhead. In the smaller rooms, where spectators are not expected to be present, light coming from various directions is often advantageous. The construction-material of operating rooms should be selected chiefly with a view to cleanliness, the color being largely a matter of taste, although this also has a bearing upon illumination. The walls and floors should be of materials that do not absorb fluids, in order that they may be washed with great thoroughness and frequency without injury, and because such materials also do not become offensive to the eye by receiving and holding stains. Floors made of asphalt are objectionable because, while they can be readily washed, they are equally readily stained, and are also very ugly and unsuited in appearance to the neat fittings of an operating room.

Floors may well be made of thoroughly seasoned wood, of marble mosaic, or even of glass. Mosaic floors are especially suitable, as they can be rubbed down with stone and sand, and so be kept exceptionally clean; besides, they are very agreeable to the eye. A thoroughly well-built wooden floor is, however, entirely satisfactory. Floors should be constructed in such a manner that their surfaces incline slightly toward the center or toward several different points, at which a proper perforated drain-opening should be placed. Free use of water is thus not restricted by any difficulty in its removal. Walls may be of marble, glass, wood, hard plaster, or iron. The three last materials require painting, preferably with a material of the nature of enamel, so that washing and rubbing may be generously indulged in. The ceiling should also be hard and well painted, and both walls and ceiling free from mouldings and other irregular surfaces such as permit of dust-accumulations. Where the walls join the ceilings and floors no sharp angles or corners should be left. These lines of union should be filled in and rounded off in curves. Rooms constructed in this manner can be washed and cleansed at every point with great rapidity and thoroughness. Fixed washstands with an abundant supply of hot and cold water should be placed at a convenient point, and should be made of materials such as marble, which do not absorb. Ingenious arrangements for turning water on and off by means of foot-pressure are not necessary, as ordinary faucets can be handled without breaking the rules of aseptic technic with the intervention of a sterilized towel or a sheet of sterilized gauze. Light colorings in operative-room construction have a great advantage that is at once appreciable.

The furniture of an operating room may be made of hard wood

with glass tops, but is better made of iron and glass. All iron material should be painted, preferably white, to avoid rust. An operating table with flat top is available for operations of almost every description, different positions being given to the patient by a proper arrangement of suitably shaped pillows with sheet rubber.

Tables especially arranged with a central drainage-opening, and with a view to altering the position of the patient in any desired manner, are preferred by many surgeons.

The accompanying illustration (Fig. 58) represents the best type of table of the kind last referred to. The framework is of iron painted

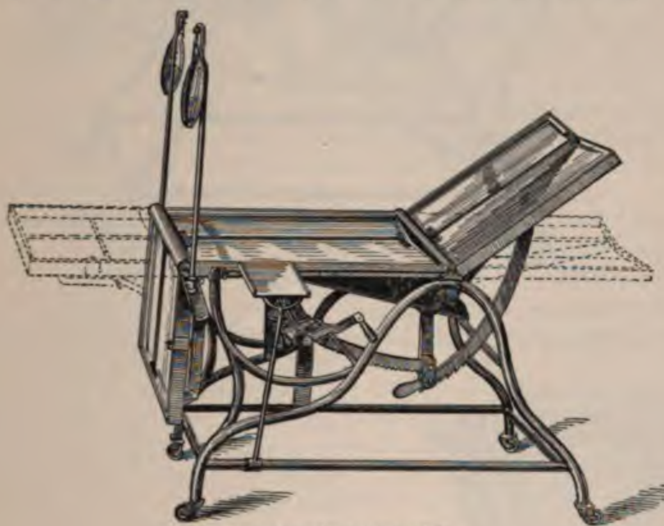


FIG. 58.—Operating table.

white. The top is made of glass, and is divided into three sections, one for the head, one for the trunk, and one for the feet. The head and foot pieces are attached to the central portion by hinges. The center table is divided by a longitudinal slit to provide for drainage. Attached to the under surface of the top of the table is a large metal pan to catch all drainage-fluids. This pan can be readily emptied and kept clean. By means of a crank movement the patient can, with the exercise of very little power, be placed in almost any position.

Generally, the less complicated in construction an operating table is, the better. Instrument tables, and tables for the pails containing sponges, and the trays containing ligatures or sutures may also be made of wood and glass, or of iron and glass.

These should all be movable, in order that their positions may be altered to suit the convenience of the operator and the nature of the operation. Every operating room should have immediately at hand, either in the room itself or in another one adjacent, a boiler for the sterilization of instruments. This may be needed at any moment during the course of an operation, in order to resterilize instruments accidentally infected, or to sterilize those which have been suddenly called for from the general case. Sterilizing apparatus for towels and dress-

ings is not needed in the operating room, because these materials are always prepared beforehand. They should, however, be not too far

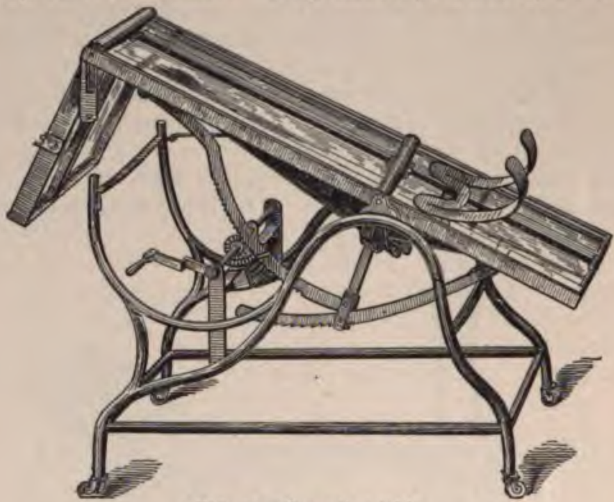


FIG. 59.—Operating table.

distant for convenience. The day has gone by for the use of expensive and complicated irrigation jars and other douching apparatus, such fluids as are used being handled more conveniently and in a more cleanly manner by the aid of pitchers and glass flasks. These are always to be filled with freshly prepared fluid, cold and hot, before an operation begins. In that way, their perfect sterilization can be guaranteed. Long india-rubber tubes for irrigating purposes, fountain syringes, and all hanging apparatus of a similar kind are objectionable on account of the likelihood of infection and the difficulty of sterilization.

FIG. 60.—Bowl to stand by operator, containing sterilized fluid, for frequent hand-washing during operation.

The general instrument case may be in the operating room, or not, according to convenience and the size of the building. It is, of course, better that there should be a special room for the continual storing of instruments. Splints, blankets, plaster bandages, and all materials that are liable to harbor dust and are not readily sterilized should be excluded from the operating room until the moment when they are needed.

It is well to have two or three benches made of wood, of different

heights, upon which the operator may stand whenever he wishes to change his relation to the patient by raising or lowering himself. If fixed washstands are set at some little distance from the operating table, some arrangement should be made so that the operator may at any moment turn from the table and cleanse his hands of blood or other fluids in a sterilized solution. A small table, supporting a bowl filled with sterile salt solution which can be frequently changed, will serve the purpose, or a special iron framework bearing a bowl made for the purpose may be supplied.

Every operating room should be provided with absolutely satisfactory artificial light, such as will perfectly take the place of daylight, if the day happens to be a dark one, or if an operation is to be done after daylight. A combination of electricity and gas furnishes an admirable light and provides against all accidents. In addition to the fixed light, which should be directly over the operating table, there should always exist a movable light, preferably electric, which can be held by an assistant so as to illuminate any particular region or cavity which the operator desires to inspect.

Operating Theaters.—Operating rooms that are intended especially for purposes of demonstration, in which accommodation for a considerable number of spectators is required, have to be constructed on a somewhat different plan. In the first place, the illumination of such rooms should be arranged with a special view to the comfort of the spectators. Every individual looking at an object sees most perfectly when the rays of illumination are, as nearly as possible, parallel with the line of vision. All light which enters the room behind the object looked at, or which reaches the eye of the spectator more or less directly from the side, serves only to diminish the power of vision. The principal light in an operating theater should therefore come from the north and enter the room just above and behind the spectators. As spectators are naturally looking somewhat downward during an operation, additional light may be let in from above, but all side-lights and all light entering from behind the operating space should be rigidly excluded. The arrangement just recommended is not the most agreeable for the operator, but it serves the purpose of his demonstration better than any other. Seats for spectators should be arranged upon an inclined plane, the angle of which, in relation to the horizontal, should be such that no one individual can in any way interfere with the vision of another sitting behind him. No accommodation should be provided for a larger number of spectators than can see accurately every detail of the operative work. The floors and seats of the auditorium should be of such materials as can be perfectly and freely washed. The floor may be of asphalt or of thoroughly laid and shellaced wood. The seats should be of wood, that being the only material which can be thoroughly cleansed and which is also comfortable to sit upon for any length of time. These seats should be supported upon single pillars, or otherwise so arranged that water may be thrown with a hose over the entire floor. If dependence for cleansing such a floor is placed upon brooms and mops, such cleansing will certainly be imperfectly done and will also be exceedingly laborious and time-consuming. At two or more points in an auditorium water-pipes should open, to

which hose can be attached, and thus the whole floor be easily and rapidly washed. Such arrangement necessarily requires a provision for drainage, openings for which should be placed at the foot of the inclined plane, in order that fluid may be rapidly carried off as soon as it has reached the lower edge of the floor. The operating space should be securely walled off from the auditorium proper, in order that no individual may be tempted to pass from one area to the other. This seems to be absolutely essential in order to preserve complete freedom from contact between spectators and those immediately engaged in the operation.

Special care must be taken that spectators do not through ignorance or carelessness, such as the placing of their feet upon the edge of this dividing wall, contaminate the operating space and the things contained in it. The operating space should be arranged in a somewhat different manner from that of a room in which no spectators are to be provided for. It should be as small as the convenience and rapid working of the operator and his assistants will permit of, for the larger the operating space, the more distant will the spectators be from the object at which they are looking. The smaller the space the nearer are the spectators brought to the operating table. Therefore, provision should never be made for the performance of more than one operation at the same time. Moreover, the attention of spectators is distracted by having different pieces of work going on simultaneously, and the rules of asepsis are very likely to be broken.

The tables for instruments and ligatures must be movable, and are to be so placed as not to interfere with the vision of the spectators. They should therefore be brought more or less to the rear of the operating table; this disposition of them forces the assistants and nurses in the same direction, thus leaving the interval between operator and audience entirely unobstructed. As the operating space is small, and as all preparations for public demonstrations are naturally carefully made on a large scale before the time for operation, all apparatus not indispensable to the proper immediate management of an operation should be excluded from the operating room. Chairs, unnecessary tables, boilers, and all such appliances are out of place on such occasions.

FIG. 61.—Iron and glass table for dressing-materials.

The remaining furniture of the operating room should consist of three or four iron stands with glass shelves and tops, mounted on rollers to admit of their being shifted about the room. These stands are for instruments, suture-trays, towels, etc.

Any extra furniture, such as wash-stands or shelves, should be placed entirely out of the way in the rear. The floor of the operating

space may be of any suitable material, preferably marble mosaic, which is non-absorbing and is very readily cleansed. In this floor there should be special drainage-openings toward which the floor must slightly incline, and the openings should be placed at points more or less distant from the operating table. The artificial-light apparatus should be so arranged that it may be swung out of the way when not in actual use. If stationary and hanging directly over the operating table at all times, it serves as a dust-accumulator at a very undesirable point. If deficiency of daylight requires that the apparatus be swung into place while an operation is going on, the entire operative area should be carefully covered with sterilized towels during this change. Of course, strictly speaking, the lighting apparatus should be kept as clean and free from dust as any other piece of furniture.

It follows from this description of an operating theater that other rooms must exist in immediate connection with it for the storing of instruments, the sterilizing of dressings, the washing of apparatus, and for the preliminary preparations of operator, assistants, and nurses. If an operating room is to be complete in every particular, there must be in close connection with it a considerable number of rooms, all of which contribute to the needs of the operating room itself. The essential rooms to accomplish this purpose may be enumerated as follows: At least two etherizing rooms, lavatory for surgeon and assistants, instrument room, room for washing instruments, sterilizing room for dressings, instruments, and water, room for storage of dressings, room for the preparation of dressings, room for splints, plaster of Paris, and rough materials of all kinds. Of course, according to the amount of work done in an operating room, and according to the possibilities in individual instances, variations in the number and arrangement of rooms may easily be made. For instance, instruments may be stored, washed, and sterilized in the same room; bandages and dressings may be prepared, stored, and sterilized in another room, and a single etherizing room will answer the needs of any but a very active service. But whatever arrangement of room is made, perfect system and order should be maintained, so that the least temptation possible may exist to break the rules of asepsis.

CHAPTER XII.

OPERATIVE AND PLASTIC SURGERY.

Instruments.—Instruments should be of the best quality and carefully selected. There is no economy in buying cheaper instruments. Surgeons should, so far as possible, learn to work with simple tools. Multiplicity or complexity of instruments for any given operation should be avoided. All instruments should be made entirely of metal, with smooth, plain surfaces; and all jointed instruments, such as clamps or scissors, should have a simple pivoted French lock. Screw-joints are not advisable, as instruments having them are not easy to clean. For all ordinary dissections, what is known as a simple dissecting-outfit is all that is needed. This will consist of knives, straight and curved scissors, two pairs of toothed dissecting-forceps (see Fig. 62), two pairs of dissecting-forceps without teeth, one aneu-

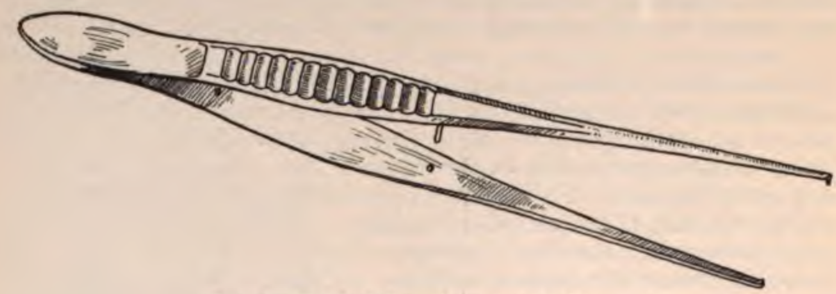


FIG. 62.—Toothed dissecting- or artery-forceps.

rysm-needle or Cleveland ligature-carrier (Fig. 63), a director or blunt dissector, plenty of hemostatic or artery-clamps (Fig. 64), and some simple form of retractor. Special operations require occasionally special instruments, the choice of which will depend on the operation in hand.

The **knives** for ordinary dissecting should be of medium size, light in weight, with metal handles, and with a moderately tapering blade (Fig. 65). (Special knives are considered under the head of Amputations, p. 329.)

Forceps should be strongly made, and must not be too narrow at the points. Those with two teeth are preferable. The strength of the spring can be varied to suit the operator. Artery-forceps, known as pressure-forceps or hemostatic forceps, are all modifications of the Spençer-Wells clamp-forceps (Fig. 64). They are indispensable in securing blood-vessels during an operation. They should be of different sizes, and with both straight and curved blades, should be strongly made, and should have a simple pivot lock.

Retractors play an important *rôle* in holding back superficial struct-

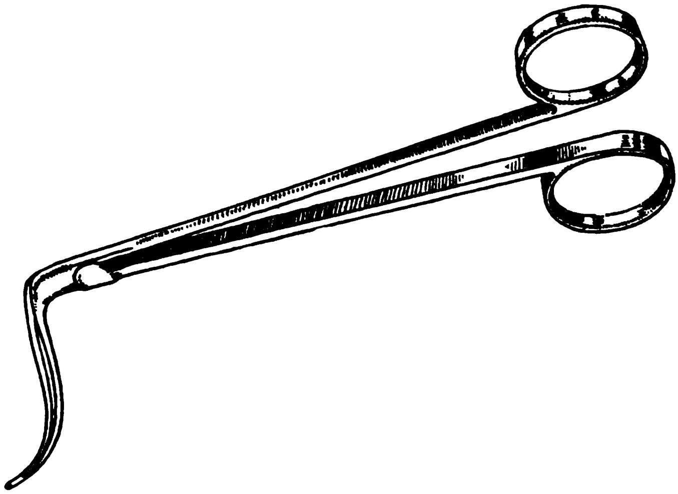


FIG. 63.—Cleveland ligature-carrier.

ures and giving access to the deeper tissues. There are many varieties. A good retractor should secure a firm hold on the tissues to be

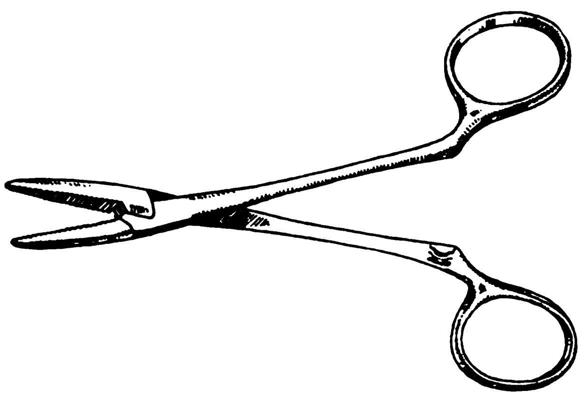


FIG. 64.—Hemostatic forceps.

held back, but should be so constructed as to inflict the least possible amount of injury to the parts. Any form of right-angled blunt retrac-

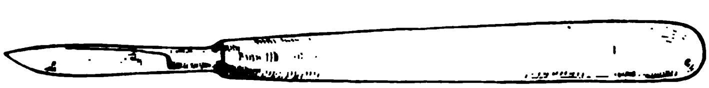


FIG. 65.—Scalpel.

tor of the proper size may be used (Figs. 66 and 67), but those with sharp teeth had better be avoided.

Needles.—For suturing skin-flaps, the best form of needle is a medium-sized glover's needle—a straight needle with triangular cut-

FIG. 66.—Small right-angled retractor.

ting-edges. In place of this, a straight lancet-pointed or surgeon's needle can be used. Hagedorn needles, straight or one-half curved,

FIG. 67.—Retractor for deep wounds.

are preferred by many surgeons for plain flap-sutures. For intestinal work, ordinary sewing-needles, without a cutting-edge, should be used. These may be straight or curved. For most intestinal work the straight needles suffice, but in some deep suturing the curved are needed. Curved needles are often useful for approximation of deep tissues, muscles, fasciæ, tendons, etc. For this a strong curved needle with a bayonet-point, or a curved Hagedorn, is best. In small needles, especially of the intestinal variety, those with the calyx eye, the self-threading type, are time-saving.

Sutures and Ligatures.—Silk, silkworm-gut, and catgut, or some form of animal tendon, are the chief kinds used by all surgeons. Silver wire has a limited use. Ligatures may be either silk or catgut. In aseptic wounds there can be no objection to silk. It can be readily sterilized and is easily handled. In septic wounds catgut is desirable, because of the tendency of silk to cause sinus-formation. For the approximation of deeper tissues, as, for instance, in hernia, kangaroo-tendon, or animal tendon in some other form, makes a desirable absorbable material. For the suturing of skin-flaps, silkworm-gut is

the ideal substance. It is non-absorbent, non-irritating, and readily sterilized. For very fine skin-sutures and especially in plastic operations on the face, sterilized horsehair will be most suitable. (For the detailed methods of sterilization of instruments, ligatures, and suture-material, see pages 276, 277.)

Technic of Dissection.—Operations should be done deliberately, and should be governed by fixed principles. The skin-incisions should be of liberal length and cleanly made. All deep dissections should be done under perfect visual control. Hemorrhage and undue injury to the tissues should be avoided. The incision should be carried downward, layer for layer, by careful strokes of the knife. Blunt dissection, or tearing of the tissues with a director or the fingers,

FIG. 68.—Knife held like a penholder.

FIG. 69.—Knife held like a violin-bow.

FIG. 70.—Table-knife position.

should be done as little as possible. The best method of dissection is that of cutting between two forceps. If the various layers of tissue are picked up by two forceps, they are put on the stretch and the vessels readily seen.

The different ways of holding the knife are shown in Figs. 68–70.

The skin-incision can be made freely and with a firm hand; but as the dissection advances and important vessels are approached, the knife should be held like a pen, and the cuts made carefully and entirely with the point.

Arrest of Bleeding.—Hemostasis should be attended to with scrupulous care during each stage of the operation. Wherever possi-

ble, vessels should be double-clamped with pressure-forceps before being divided. All bleeding points should be secured with hemostatic forceps. Many of the smaller vessels require no ligature after being compressed for some time. Especially is this true of the vessels in the skin-flaps. In case of doubt, it is a safe rule to ligate all points that have been caught during the operation, for many small vessels which do not show signs of bleeding on removing the artery-clamps may bleed when the reaction from the operation and anesthetic begins. Torsion of the smaller vessels is not a reliable means of hemostasis. In certain instances of venous oozing, and especially in operations on inflamed and friable tissues, it may be necessary to pass a ligature in a curved needle around the bleeding spot and control the hemorrhage by constricting a comparatively large area. Many cases of slight general oozing can be checked by temporary pressure with gauze pads, or by the use of hot sterile water or salt solution. In exceptional cases, where large areas of inflamed tissue are denuded, it may be necessary to use the actual cautery.

THE LIGATURE OF ARTERIES.

General Principles.—In doing this class of operations it is wise to adhere strictly to the rules applying to the particular vessel, as in this way only will the possibility of missing the vessels be avoided by those unfamiliar with the operation. In applying a ligature to large vessels the proximity of important branches should be avoided, as otherwise the formation of a secure thrombus may be seriously interfered with. Throughout this article little stress is laid upon the exact length of the incision, because it is believed that it must vary so much with different patients that exact measurements are more misleading than otherwise, and that the incision should always be large enough to give ample room. This statement, however, does not apply to the opening made in the sheath of the vessel, which should be made as small as possible, thereby avoiding damage to the vasa vasorum, by which the coats of the artery are nourished. It is not necessary to separate the venæ comites from the smaller vessels; troublesome oozing may be avoided by tying them with the artery *en masse*. In this same connection, less stress is laid upon the direction in which the needle is passed than has usually been done; but when the dissection is freely made and the needle passed *by sight* rather than by feeling, the danger of wounding vessels and including nerves in the ligature is much diminished; and the use of a Cleveland needle is advised, as being more convenient and easier of manipulation. For vessels of moderate size catgut is satisfactory, but for larger vessels silk is a safer material.

The **anatomy of the supraclavicular region** with reference to the innominate and subclavian arteries. The innominate bifurcates opposite the right sternoclavicular articulation. The subclavian artery arches upward, so that its highest point is ½ to 1 inch above the clavicle, and ends underneath the middle of that bone. The subclavian vein lies behind the clavicle on a lower level than the artery, and separated from it by the scalenus anticus muscle. The vein is held to the clavicle by a portion of the deep cervical fascia. The phrenic nerve crosses the scalenus anticus obliquely and passes downward between it and the subclavian vein. The relations of the first part of the artery vary on the two sides. On the *right*, the artery is in contact with the pleura below and behind.

The pneumogastric nerve passes in front, and its recurrent branch, turning below the artery, runs upward behind. The internal jugular and subclavian veins unite in front of this portion to form the right innominate vein, which passes downward in front of the outer side of the subclavian and innominate arteries. The left innominate vein is not in relation to its artery, but crosses the origin of the left common carotid and unites with its fellow in front of the innominate artery. The *left subclavian* is an inch longer than the right and lies at a deeper level; its outer side is in contact with the pleura. Behind and internally lie the esophagus, recurrent laryngeal nerve, and trachea. The thoracic duct, at first on the inner side, soon arches outward and forward, behind the internal jugular vein, to join the subclavian at their angle of union.

The second and third portions are similar on the two sides. The third part of the artery has rarely more than one branch, is most superficial, and is therefore the portion ligatured by election. It lies in a triangle bounded below by the clavicle, on the upper and outer side by the posterior belly of the omohyoid muscle, on the inner side by the outer border of the sternomastoid. The inner cord of the brachial plexus is behind the artery, where it rests on the first rib. The subclavian vein is below and anterior. At the lower outer margin of the sternomastoid the external jugular joins the latter vein. The supraclavicular fascia is crossed superficially from above downward and outward by the supraclavicular nerves. Under the cervical fascia the field of operation is crossed by several large veins, namely, the transverse cervical, the suprascapular, the posterior external jugular, and the inferior thyroid. Troublesome hemorrhage may arise from these unless they are tied before division.

Ligature of the Innominate Artery (Fig. 71).—Ligature of this artery is rightly regarded as one of the most difficult and danger-

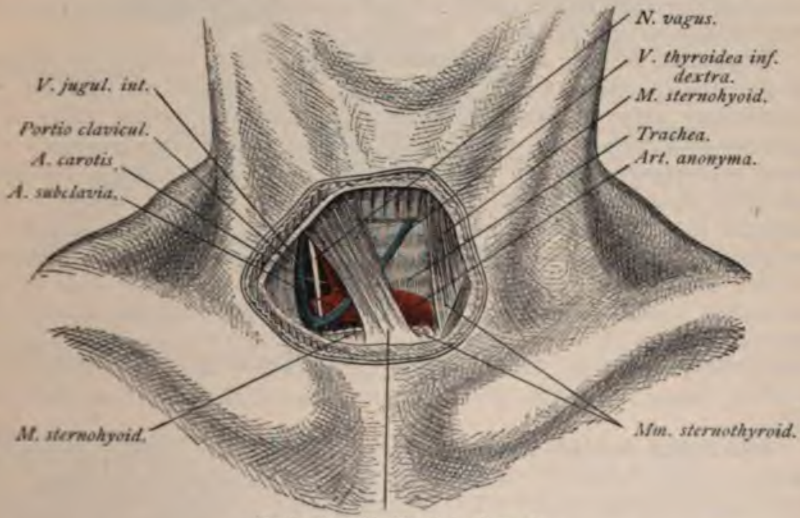


FIG. 71.—Topography of the truncus anonymus in the fossa jugularis (after Loebker).

ous operations. Twenty-nine authentic cases were reported by Burrell in 1895. Of these, 1 case lived ten years after operation, and 1, one hundred and four days; all the others died within two months, from shock, sepsis, or secondary hemorrhage; though in Burrell's case, which lived one hundred and four days, death may be properly attributed to coexisting cardiac disease. With our improved technic, the mortality from sepsis and attendant secondary hemorrhage can surely be diminished. In such a formidable procedure, it seems wise to disregard soft parts, and even bone, and the following operation is therefore advocated:

By Resection of a Portion of the Sternum.—An incision is made from the level of the cricoid cartilage along the anterior border of the sternomastoid down the middle of the sternum to the gladiolus. The lower attachments of the right sternomastoid, sternohyoid, and sternothyroid muscles are divided close to the bone and allowed to retract. A spatula is placed between the sternum and the large veins. The upper outer part of the manubrium with the sternoclavicular articulation and insertion of the first rib should then be removed with a chisel or rongeur forceps. The large inferior thyroid veins are found and tied between ligatures. The innominate artery is thus freely exposed, and the surrounding structures may be identified by sight as well as touch. With the finger or a blunt dissector the areolar tissue is gently separated from the vessel. In front lies the junction of the left and right innominate veins, dilating and contracting with respiration. To the outer side are found the phrenic and pneumogastric nerves, with the pleura. Behind, and on the inner side, the artery rests on the trachea. Avoiding all these structures, two large silk ligatures are passed about the vessel, ½ inch apart. These are tightened gently and firmly until pulsation ceases in the distal portion. In aneurysm, the common carotid and vertebral arteries should also be ligatured, to prevent collateral circulation in the sac.

Ligature of the Subclavian Artery.—The incision for ligature of the first portion of the left subclavian is similar to that for the innominate artery, though, of course, on the opposite side. The muscles and deep cervical fascia are divided in the same manner. No bone will require removal unless the vessel is to be tied near the arch, where it is situated even deeper than the innominate artery. The internal jugular and left innominate veins are retracted, respectively, outward and downward. The thoracic duct offers the chief difficulty. Search should be made for the main trunk to the inner side of the ascending subclavian. It arches at a higher level than the artery, and frequently ends by two or three branches. When the ligature is passed from within outward, the pneumogastric nerve and duct should be pushed inward and the phrenic nerve carefully defined on the outer side.

The Right Subclavian in its First Portion.—A similar incision is made, ending, however, an inch below the sternoclavicular joint. No bone need be removed. The sternomastoid is divided and retracted outward with the internal jugular vein. The phrenic nerve is found along the inner border of the scalenus anticus; the pneumogastric nerve lies in front of the vessel. The numerous arterial branches must be isolated and pushed aside, and the ligature passed *by sight* below them. This is a very dangerous procedure, there having been only 3 successful cases reported.[1]

The Second Portion.—The incision and steps are the same as for the ligation of the third portion, next to be described. Avoiding the phrenic nerve, which is held to the inner side, the scalenus anticus is cautiously divided by a transverse incision and allowed to retract. The artery lies immediately behind it with one or more branches. The ligature is passed from before backward.

[1] Halsted, 1892; B. F. Curtis, 1897; Allingham, 1899.

The Third Portion (Fig. 72).—This part of the artery is relatively easy of access, and is ligatured for hemorrhage, aneurysm, or as a preliminary to amputation of the upper extremity. The artery has similar relations on both sides of the body. Having previously pulled the skin over the clavicle firmly downward, a 4-inch incision is begun, an inch from the sternoclavicular joint, and carried along the clavicle down to the bone. The parts are allowed to retract, and the deep fascia is then divided. The external jugular vein at the posterior border of the sternomastoid is easily tied between two ligatures. The shoulder must now be pulled down as far as possible. In muscular subjects the space between the clavicular attachments of the trapezius and sternomastoid is often narrow, and part of these muscles may require division. The supraclavicular fat is gently separated from the

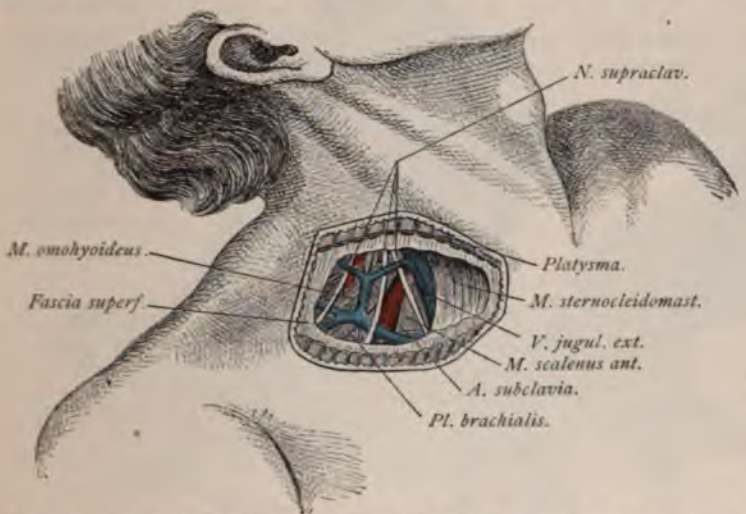


FIG. 72.—Topography of the subclavian artery above the clavicle, outside the scalenus anticus muscle (after Loebker).

underlying structure and retracted upward and inward. The operator, standing at the patient's head, next defines the insertion of the scalenus anticus into the tubercle of the first rib. This is best done by inserting the forefinger deeply into the wound, using the right hand in right incisions, and the left in left incisions. The artery will be felt pulsating behind and to the outer side of the tubercle. The vein lies in front, and is rarely seen. Posterior to the vessel lie the inner cords of the brachial plexus. In this and similar operations in the neck, the smaller veins which are encountered should be tied between two ligatures; arterial twigs should be similarly treated. By such careful technic staining of the areolar tissue with blood is avoided and the dissection far more clearly made. With the artery in plain sight, the sheath is carefully incised and the ligature passed in either direction, preferably from the vein.

Ligature of the Superior Thyroid Artery (Fig. 73).—This artery arises from the external carotid at the upper edge of the thyroid

cartilage, and passes inward and downward, sending branches to the thyroid muscles and gland. The superior laryngeal nerve is just above and to its inner side. The only indications for tying this vessel are vascular enlargements of the thyroid gland, and as a preliminary to thyroidectomy.

Operation.—An incision, 3 inches long, is made along the inner border of the sternomastoid, with its center opposite the upper part of the tumor. The skin and deep fascia are divided, and the sternomastoid muscle drawn to the outer side. Search is made at the upper inner aspect of the lateral lobe of the thyroid, and the anterior branch

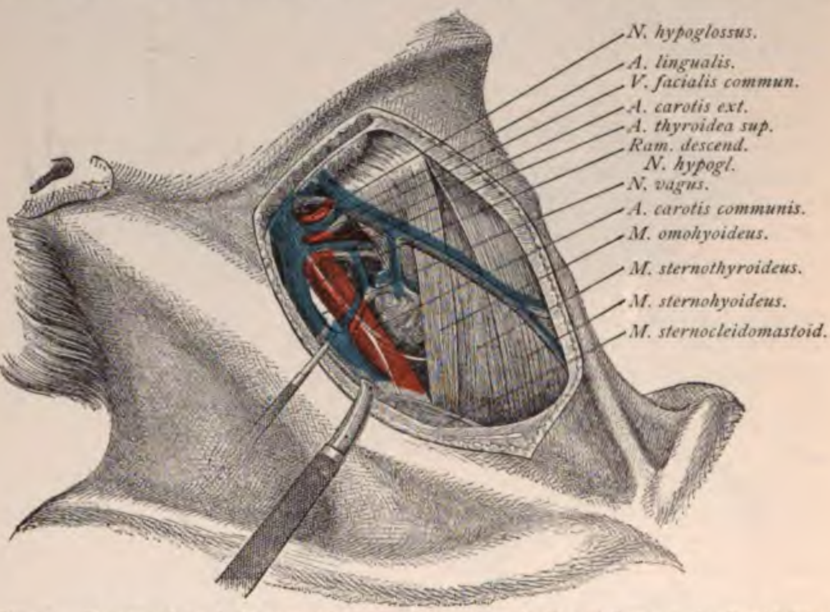


FIG. 73.—Topography of the carotid artery from the cricoid cartilage to the hyoid bone (after Loebker).

of the artery easily found. This is ligatured, or the artery followed higher up in the neck and there tied.

Ligature of the Inferior Thyroid Artery.—This branch arises from the thyroid axis, and passes upward to the level of the cricoid cartilage, where it bends sharply inward and divides into two branches behind the lower part of the lateral lobe of the gland. The recurrent laryngeal nerve passes upward in the groove between the trachea and esophagus, and usually behind the terminal branches of the artery. The vessel rests on the longus colli muscle close to the vertebral column.

Operation.—A 3-inch incision is made, opposite the cricoid cartilage, along the anterior border of the sternomastoid. This muscle is retracted to the outer side with the common sheath of the great vessels, while the larynx and thyroid gland are pulled inward. The inferior thyroid artery can always be recognized from its horizontal direction. Half an inch below the carotid tubercle, the sympathetic cord crosses

it at right angles, and should be pushed to the outer side. The recurrent laryngeal nerve, lying near, can also be recognized by its vertical direction, nearer the median line. The ligature is passed from below upward, away from the inferior thyroid veins, and tied.

Ligature of the Vertebral Artery.—This artery arises from the subclavian close to the inner border of the scalenus anticus. In the groove between this muscle and the longus colli it runs upward to the transverse process of the sixth cervical vertebra.

Operation.—The operation is the same as that for ligature of the inferior thyroid, but more difficult, as the vertebral artery lies deeper under the prevertebral fascia. This fascia is vertically incised ½ inch below the carotid tubercle. The artery is here ligatured just above the bend of the inferior thyroid, which is pushed downward. The vertebral vein is best ligatured with the artery.

Ligature of the Axillary Artery (Fig. 74).—This vessel extends from the lower border of the first rib to the lower margin of the teres

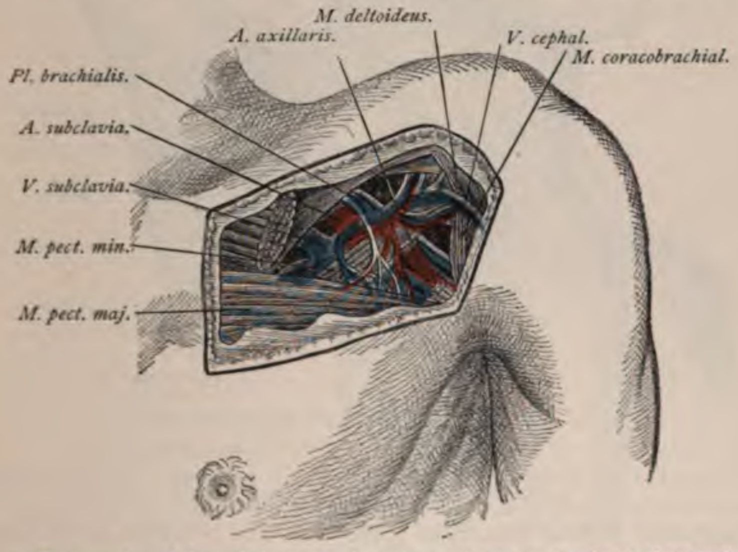


FIG. 74.—Topography of the subclavian and axillary arteries on the front chest-wall (after Loebker).

major. If the arm is abducted to a right angle, the artery lies under a line drawn from the middle of the clavicle to the middle of the bend of the elbow. It is divided into three portions by the pectoralis minor. Above this muscle the costocoracoid membrane sends an expansion to the axillary vein, which lies internal and anterior to the artery. On the outer side run the cords of the brachial plexus. The cephalic vein passes upward along the inner border of the deltoid, and between it and the pectoralis major; having pierced the costocoracoid membrane, it empties into the axillary vein.

Operation.—A 4-inch incision should be made over the interspace between the deltoid and pectoralis major, which muscles should then be widely retracted. The cephalic vein, previously defined, is left in

the outer margin of the wound. The costocoracoid fascia is incised with care, and the axillary vein found and pulled inward. Deeply placed and slightly to the outer side of it lies the artery. The ligature is passed away from the adjacent nerve-cords. This operation is more bloody and difficult than ligature of the third part of the subclavian.

Ligature in the Axilla.—An incision 3 inches long is made at the junction of the anterior and middle thirds of the axilla, along the posterior border of the coracobrachialis muscle. The deep fascia is incised and the two lips of the wound *evenly* retracted. The vein is below and slightly overlaps the artery. Above is the median nerve;

FIG. 75.—Topography of the axillary artery (after Loebker).

below are the internal cutaneous and ulnar nerves. These structures should be retracted, and the artery isolated and tied.

Ligature of the Brachial Artery.—The brachial artery extends from the junction of the anterior and middle thirds of the axilla to the inner side of the biceps tendon at the middle point of the bend of the elbow. Opposite the neck of the radius it divides into the ulnar and radial arteries; the median nerve follows the vessel closely. At first, the median nerve lies to the upper and outer side of the artery, which it crosses, usually in front, about the middle of the arm, and continues its course along the inner side. The artery lies in the groove between the biceps and triceps muscles. The brachial venæ comites are irregular in size: just above the middle of the arm the basilic vein pierces the deep fascia, to unite with them to form the axillary vein.

Operation at the Middle of the Arm.—An incision is made over the line of the artery and carried through the deep fascia. The basilic vein should be made tense and avoided; the biceps muscle is disclosed and drawn outward; the sheath surrounding the artery, veins, and nerves is carefully incised; the artery separated and ligated. Occa-

sional high division of the brachial artery should always be borne in mind.

Ligature at the Bend of the Elbow.—An oblique incision is made along the inner border of the biceps tendon, ending at the bicipital fascia. By this incision superficial veins may usually be avoided. The artery is exposed, lying between the bicipital tendon on the outer side and the median nerve on the inner side, and resting on the brachialis anticus muscle. The venæ comites may be included in the ligature.

Ligature of the Radial Artery.—This artery runs from the bifurcation of the brachial to the inner side of the styloid process of the radius. The artery is covered in its upper third by the belly of the supinator longus, then runs superficially along its inner border. The radial nerve is in relation to the vessel only in the middle third, and lies to the radial side.

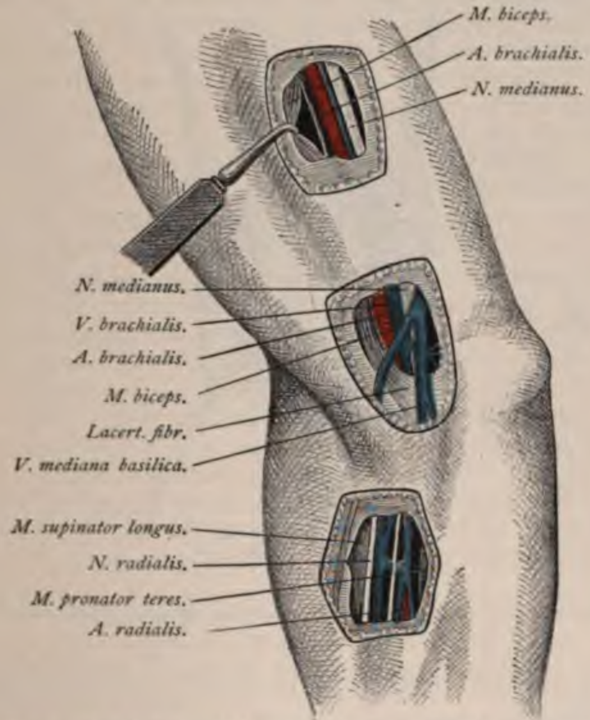


FIG. 76.—Topography of the brachial and radial arteries (right arm) (after Loebker).

Ligature in the Upper Third.—An incision, beginning 2 inches below the bend of the elbow, is made over the line of the artery, and is carried through the deep fascia. The supinator longus is raised and drawn to the outer side. The pronator radii teres, of which the oblique fibers are easily recognized, is pulled to the inner side. The artery is disclosed with its venæ comites and tied.

Ligature in the Lower Third.—An incision 2 inches long is made upward in the line of the artery, beginning an inch above the tip of the

styloid process. The artery is found immediately beneath the deep fascia. On the ulnar side is the tendon of the flexor carpi radialis. The radial nerve is not seen. The artery is isolated and tied.

Ligature of the Ulnar Artery.—The line for incision in tying this artery runs from the internal condyle to the radial side of the pisiform bone. In the lower two-thirds of the forearm the artery lies directly under this line. In the upper third the vessel is covered by the superficial muscles arising from the internal condyle, and is situated under a slightly curved line, with the convexity inward, drawn from the upper border of the middle third to the point of bifurcation. The

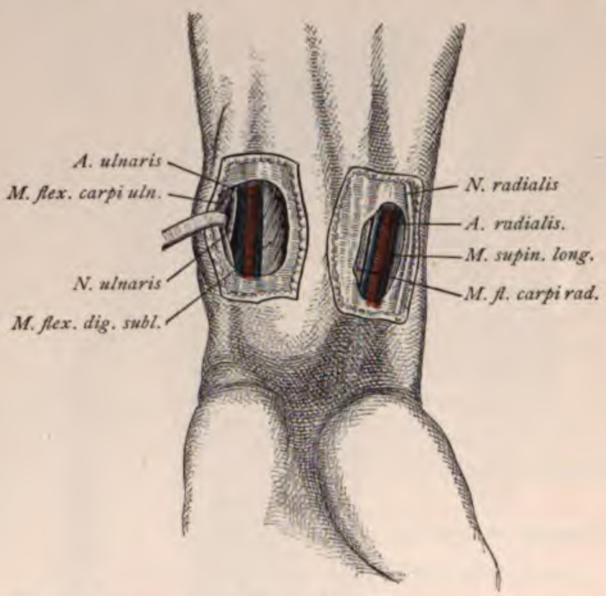


FIG. 77.—Topography of the radial and ulnar arteries (after Loebker).

ulnar nerve joins the artery above its middle and runs to the wrist on its ulnar side.

The Junction of the Upper and Middle Thirds of the Arm.—An incision 4 inches long, with its center at the above point, if made on the line, will disclose the intermuscular space between the flexor carpi ulnaris and sublimis digitorum muscles. This septum will be marked as a white or yellow line under the deep fascia. Should any difficulty be met, a superficial transverse incision through the muscles will be of great help. On carefully separating these two muscles and pulling the superficial flexor inward, the ulnar nerve comes first into view, lying on the deep flexor; a little outward, but in the same plane, is found the ulnar artery. A needle is passed from the nerve about the veins and artery.

In the Lower Third.—An incision through the deep fascia is made just to the radial side of the tendon of the flexor carpi ulnaris. The muscular belly extends almost to the wrist, and should be retracted to

the ulnar side. The ligature is passed from the nerve which lies on the ulnar side.

Ligature of the Common Carotid.—In operations in the neck the position of the head is most important. The face should be turned *from* the side to be operated upon, the shoulder depressed, and a firm pillow placed behind the extended neck; later the head may be flexed to relax the muscles. The line of the carotid artery runs from the sternoclavicular articulation to a point midway between the angle of the jaw and the mastoid process. The carotid divides opposite the upper border of the thyroid cartilage. Here the external carotid is anterior, the internal posterior. This relation soon changes, the external carotid lying to the outer side and posterior to the internal carotid. The length of the right common carotid is usually $3\frac{1}{2}$ to 4 inches, the left an inch more. The internal jugular vein emerges from the skull behind the internal carotid; it soon passes to the outer side of the artery, greatly increased in size by the addition of the temporofacial veins at the level of the hyoid bone, and runs down the neck on the outer side of the common carotid artery, which it overlaps. The pneumogastric nerve lies behind and between the common carotid and internal jugular vein, and is enclosed in a separate compartment of the common sheath. The hypoglossal nerve curves inward about the occipital artery at its origin, sending off the descendens hypoglossi nerve, which runs downward over the common sheath. As the sternomastoid muscle passes to its insertion, it crosses the common carotid obliquely, so that the lower portion of the artery comes to lie deeply near its posterior border. The omohyoid muscle crosses the artery at the level of the cricoid cartilage. The point of election is above the tendon of this muscle. As ligature of the common carotid will not completely control hemorrhage from the external carotid branches, owing to the free anastomosis, and as brain-symptoms follow ligature of the common carotid in about 20 per cent. of all cases, this operation should never be done when ligature of the external carotid alone will suffice.

Operation.—A 3-inch incision downward from the cricoid cartilage is made along the anterior border of the sternomastoid. The skin, subcutaneous tissue, platysma, and deep cervical fascia are divided. The sternomastoid is retracted to the outer side. Above the omohyoid the artery is quite superficial. The common sheath is carefully opened on its inner side, to avoid the jugular vein. The artery is isolated with a blunt dissector. The needle is passed from the vein, avoiding the pneumogastric nerve behind. Below the omohyoid the artery lies deep in the neck, under the sternomastoid. When an aneurysm exists in the upper part of the artery, this muscle may require division before the ligature can be properly applied.

Ligature of the Internal and External Carotids at their Origins.—An incision of 3 inches is made along the anterior border of the sternocleidomastoid, from the angle of the jaw downward through the deep fascia. The external jugular vein should be divided between two ligatures, and the muscle retracted outward as before. The temporofacial vein, as it unites with the internal jugular, should be pulled upward and outward. By its branches the external carotid may

be distinguished from the single trunk of the internal carotid lying behind. The superior laryngeal nerve passes along the inner side of the internal jugular to the larynx. The pneumogastric nerve must be clearly seen. The ligature is passed from without inward about either artery.

Ligature of the Lingual Artery.—The lingual artery, a branch of the external carotid, is given off at about the level of the greater cornu of the hyoid bone, where it is deeply placed. It passes forward beneath the stylohyoid and posterior belly of the digastric, and enters the submaxillary triangle, which is bounded by the anterior and posterior bellies of the digastric and the ramus of the jaw. Shortly after entering this triangle the vessel passes behind the hyoglossus muscle, by which it is covered throughout the rest of its course. The hypo-

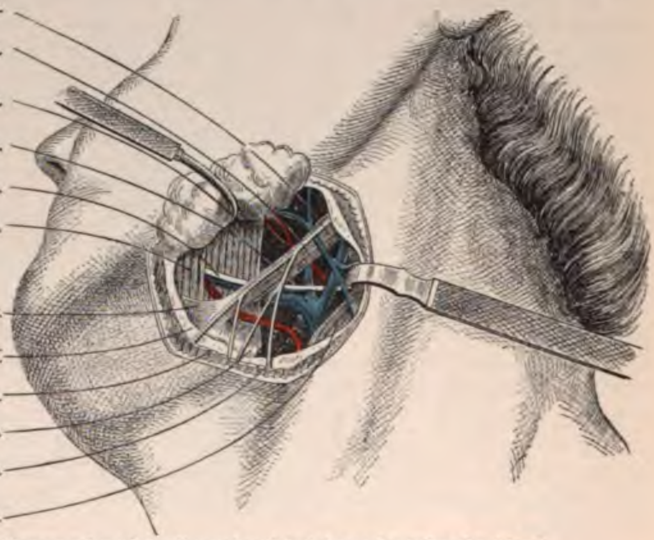


FIG. 78.—Topography of the lingual and facial arteries (after Loebker).

glossal nerve also crosses the submaxillary triangle in a direction parallel to the jaw and superficial to the hyoglossus muscle, which thus separates the nerve from the artery. The triangle formed by the two bellies of the digastric below and the hypoglossal nerve above is the most convenient situation in which to secure the lingual artery, and is readily found.

Operation.—A curved incision is made, starting at the angle of the jaw and descending to the level of the hyoid bone, and then up again to a point about 1 inch to one side of the symphysis of the jaw. This cut is deepened so as to divide the skin, platysma, and the deep fascia attached to the hyoid bone. The flap thus formed is turned up, carrying with it the submaxillary gland, and the digastric muscle and hypoglossal nerve come into view. The mylohyoid muscle may encroach considerably upon the triangle, and its posterior fibers should be divided if necessary. The field having been fully exposed, the hyoglossus muscle is divided close to the hyoid bone and turned upward, when

the lingual artery will be seen running nearly parallel to the course of the hypoglossal nerve. There is no vein in close relation to the artery.

Ligature of the Facial Artery.—The facial artery leaves the carotid generally in close relation to the lingual artery and passes beneath the hyoid muscle to the deep surface of the submaxillary gland, under cover of which it runs until it reaches the masseter, when it turns abruptly upward along its anterior border, where the pulsation can be felt. The vein lies posterior to the artery and crosses the submaxillary gland superficially.

Operation.—The vessel is best exposed by an incision parallel to the ramus of the jaw, with its center at the anterior border of the masseter muscle. In this way the vessel can be found without difficulty; the small branches of the facial nerve are not injured, and the scar is better placed. The ligature is generally passed from behind forward, but the vein is not always very close to the artery.

Ligature of the Occipital Artery.—The occasions on which this vessel will be tied must be exceedingly rare, as in cases of cirsoid aneurysm of the scalp the afferent and efferent vessels will be tied as they appear, without regard to their position. The vessel may be found by making an incision from the tip of the mastoid process backward and slightly upward for about 2 inches. The aponeurosis of the sternomastoid and the insertion of the splenius must be freely divided, when the pulsation of the vessel can be felt.

Ligature of the Temporal Artery.—The temporal artery is the linear continuation of the external carotid, which divides into its terminal branches, the temporal and internal maxillary, at about the level of the neck of the lower jaw. The temporal artery is at first deeply placed in the substance of the parotid gland; but at about the level of the external auditory meatus it becomes superficial, running upward in front of the ear over the root of the zygoma, and divides into its terminal branches at a variable distance above that level. The temporal vein and the auriculotemporal nerve lie between it and the ear. It is best exposed by a vertical incision 1 inch in length, a finger's breadth in front of the ear, starting at the level of the zygoma and running upward. This will avoid danger of injuring the branches of the facial nerve, which are below the zygoma at this point.

Ligature of the Abdominal Aorta.—As far as we are aware, the abdominal aorta has never been successfully tied, though several attempts have been made. The technic of the operation presents no difficulties. The incision should be made through the left rectus muscle, about $\frac{1}{2}$ inch from the median line, with its center at the level of the umbilicus. The peritoneal cavity should be freely opened, and the intestines walled back with gauze. The position of the vessel can be told by feeling the pulsations with the finger; the posterior parietal peritoneum is incised, and the ligature passed from the right side, to avoid the vena cava.

Ligature of the Common Iliac Artery.—The position of the common iliac artery is indicated by a line drawn from the left side of the umbilicus to the center of a line connecting the anterior superior spine of the ilium with the symphysis pubis. The vessel varies in length from $1\frac{1}{2}$ to 3 inches, and extends from the fourth lumbar verte-

bra to the sacro-iliac synchondrosis, where it divides into the external and internal iliacs. The relations of the vessels to veins differ somewhat on the two sides, the left being in relation only with the left common iliac vein, while the right has the right common iliac vein behind its lower part, the left common iliac vein behind it above the middle, while the lower end of the vena cava lies behind its upper end. Both vessels are in the same relation to the ureters, which cross at or near the bifurcation.

After ligature of the common iliac the collateral circulation is carried on through the anastomosis of the internal mammary with the deep epigastric, of the circumflex iliac with the lumbar arteries, and of the visceral branches of the internal iliac with those of the other side. The older writers laid great stress on the extraperitoneal method of tying the common iliac, but we do not believe that the method was chosen for any reason other than the fear of opening the peritoneal cavity—a procedure that is fraught with but little danger to-day. The extraperitoneal method necessarily results in damage to the retroperitoneal adipose tissue, which we believe to be far more liable to infection than the peritoneum, and can hardly avoid some damage to the lumbar vessels and muscular branches which play an important part in the collateral circulation. The choice of incision lies between that in the median line and that through the rectus muscle, and the question must be decided by the preference of the individual operator. In either case, the incision should start at about the level of the umbilicus, and be continued downward a variable distance according to the thickness of the abdominal wall. The use of the Trendelenburg position will facilitate exposure of the field by removing the mass of small intestine, and the vessel will be readily found running along the brim of the pelvis. The peritoneum covering the vessel may be incised somewhat to the outside, and the opening thus made freely enlarged with the fingers. The ureter is in relation only with the lower part of the vessel, and need not be seen; but its position will be generally so obvious that there is little danger of its being injured. The chief difficulty will be found in separating the vessel from the veins; and it is important to have a thoroughly good exposure and plenty of room. After the ligature is tied, the peritoneum covering the vessel should be closed with sutures, and the remainder of the operation completed as in any clean laparotomy. It will probably be wise to close the wound without drainage.

Ligature of the Internal Iliac.—The internal iliac runs downward and forward from the sacro-iliac synchondrosis. It is in relation anteriorly with the ureter and at its upper part with the external iliac vein, posteriorly with the internal iliac vein; it rests on the nerves of the sacral plexus. It is exposed by an incision similar to that for the common iliac, but, owing to its depth and to the fact that on the left it is partially covered by the rectum, the operation is somewhat more difficult. Ligature of this artery is rarely done except for gluteal aneurysm; though recently it has been advocated for uterine fibroid and for hypertrophy of the prostate.

Ligature of the External Iliac.—The older operators usually preferred to tie the external iliac in place of the common femoral, for fear of secondary hemorrhage; but at the present time this danger has

decreased so much that the choice must be made upon other grounds. The close proximity of large branches makes ligature of the common femoral a more difficult procedure, though the collateral circulation is somewhat less good after the latter operation. The vessel lies in the line already indicated for the common iliac, and has no branches of

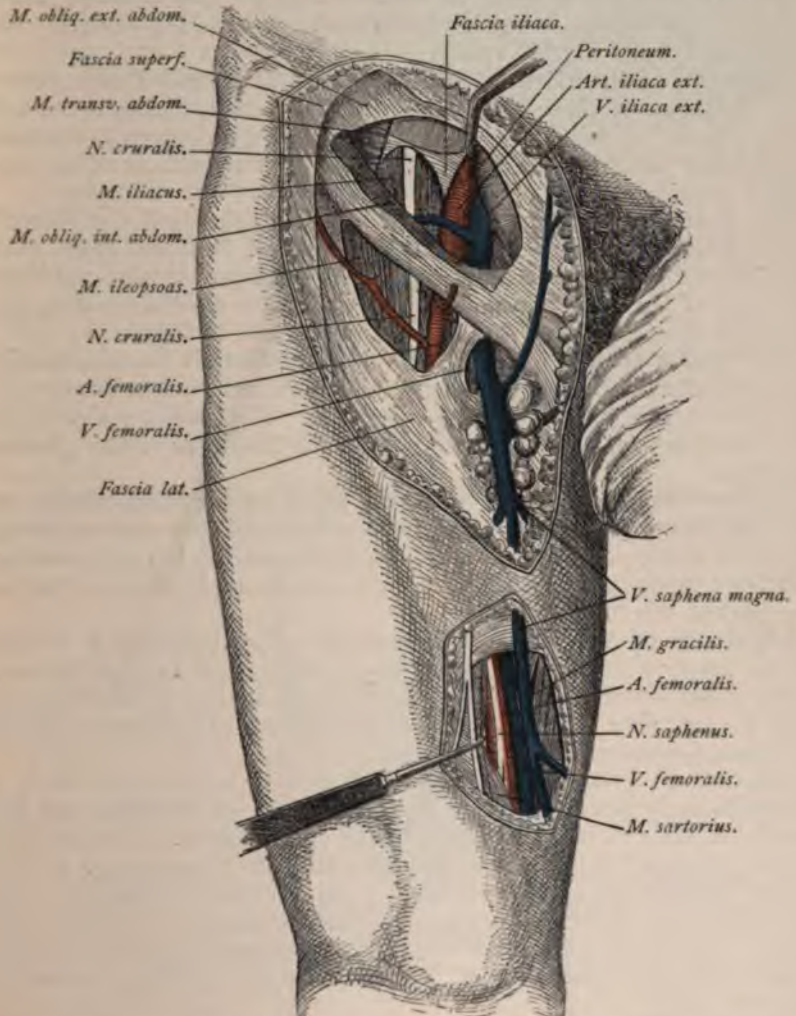


FIG. 79.—Topography of the external iliac and femoral arteries (after Loebker).

importance except near its termination, where it gives off the deep circumflex iliac and the deep epigastric. The vein lies at first below and later to the inner side, while the genital branch of the genitocrural nerve lies rather on its outer side. Ligature of this vessel is most commonly done prior to amputation at the hip-joint and for femoral aneurysm, and the exact position of the vessel is most readily found by feeling the pulsation.

The extraperitoneal method is that most commonly used. The patient should be placed in the dorsal position, with hips elevated so as to hyperextend the thigh. The incision is made 1 inch above and parallel to Poupart's ligament, with its center over the line of the vessel. The deep epigastric artery crosses the line of this incision, and should be avoided, as it forms an important part of the collateral anastomosis. The incision is carried down to the peritoneum, which is then pushed back, exposing the vessel.

Ligature of the Gluteal, Sciatic, and Internal Pudic Arteries.—Ligature of these arteries, except for traumatic aneurysm, will rarely, if ever, be done. In cases of hemorrhage following wounds, the bleeding point will be sought and secured regardless of its anatomical position.

The **gluteal artery** emerges from the pelvis above the pyriformis muscle, which is the guide to the vessel, and will be found at the middle third of a line drawn from the posterior superior spine of the ilium to the top of the great trochanter. The incision should be free, and should be deepened until the pyriformis muscle is found.

The **sciatic artery** is placed below the pyriformis muscle, and its course is indicated by a line drawn from the posterior superior spine of the ilium to the tuberosity of the ischium. The incision should be made over the center of this line, parallel to the fibers of the gluteus maximus.

The **internal pudic** artery leaves the pelvis by the same opening as the sciatic artery; but it immediately re-enters, and then runs up along the ramus of the pubes. It is most readily secured in the perineum by an incision made on a line extending from the symphysis pubis to the inner part of the tuber ischiæ.

Ligature of the Femoral Artery.—The importance of the femoral artery in operative surgery is not altogether an historic one, for the vessel is not infrequently wounded, and ligature of this vessel is at the present time the most prominent method of treating popliteal and femoral aneurysms.

The course of the vessel may be indicated by a line drawn from a point midway between the anterior superior spine of the ilium and the symphysis pubis to the adductor tubercle of the femur. For the purpose of operation the vessel may be divided into three parts: 1. The *common femoral*, that part extending from Poupart's ligament to the point of origin of the profunda femoris, a distance of from 1 to 2 inches. 2. The *superficial femoral*, that part extending from the origin of the profunda to the apex of Scarpa's triangle. 3. The *femoral in Hunter's canal*.

Ligature of Common Femoral.—This operation is somewhat unsatisfactory, owing to the close proximity of large branches and to the fact that, in the past, secondary hemorrhage has been of frequent occurrence. The vessel is exposed by an incision starting at Poupart's ligament and extending downward 3 to 4 inches in the line indicated above. It is covered only by the skin, superficial fascia, and iliac fascia, which latter should be cautiously divided. The vein lies to the inner side, and is included in a compartment of the same sheath as the artery. This sheath should be freely opened, the artery separated from the

vein, and the needle passed from within outward, keeping close to the artery. The anterior crural nerve lies $\frac{1}{2}$ inch to the outer side, and should not be seen. It is advisable to ascertain the location of the circumflex and profunda arteries before the ligature is tied.

Ligature of Superficial Femoral.—The superficial femoral is readily accessible, being covered only by the skin and superficial fascia. The thigh should be flexed and abducted, and an incision made with its center 4 to 5 inches below Poupart's ligament, in the line of the vessel. The sartorius muscle is directly to the outer side, and will be recognized by the oblique direction of its fibers, and drawn outward, revealing the artery, with the vein to the inner side and somewhat behind. The needle should be passed from within outward.

Ligature in Hunter's Canal.—Hunter's canal occupies the middle third of the thigh, which should be partially flexed and abducted, as in the previous operation. The incision is made a finger's breadth to the inner side of the line of the vessel, so as to find the sartorius muscle. This is drawn inward, exposing the aponeurotic covering of the canal between the adductors and the vastus internus, in which the vessel lies. The internal saphenous nerve should be found lying upon the anterior surface of the artery, while the vein lies behind and somewhat to the inner side. The ligature should be passed from within outward and upward, to avoid the vein, care being taken not to include the nerve.

Ligature of the Popliteal Artery.—The popliteal artery is most readily reached in the middle of the popliteal space midway

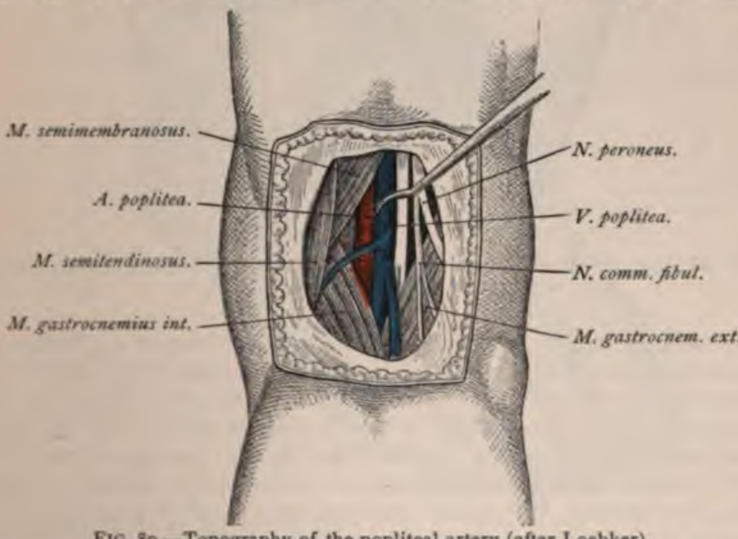


FIG. 80.—Topography of the popliteal artery (after Loebker).

between the condyles of the femur. It lies directly upon the bone, with the vein behind it, and the internal popliteal nerve superficial to the vein and slightly to the inner side. The patient should be placed on his face, with the leg extended, and a free incision made through the skin, $\frac{1}{2}$ inch outside of the middle line, to avoid the internal saphe-

nous vein. The nerve can be felt as a tense cord, and drawn to one side, when the vein will be found embedded in a mass of adipose tissue and intimately adherent to the artery. It should be carefully but completely separated, and all bleeding controlled. If the dissection has been efficiently done, the ligature may be passed in either direction.

Ligature of the Anterior Tibial Artery.—A line drawn from the inner side of the head of the fibula to the center of the ankle-joint will indicate the course of the vessel. It lies upon the interosseus membrane in the upper two-thirds, and upon the anterior surface of the tibia in the lower third. The vessel has upon its inner side the

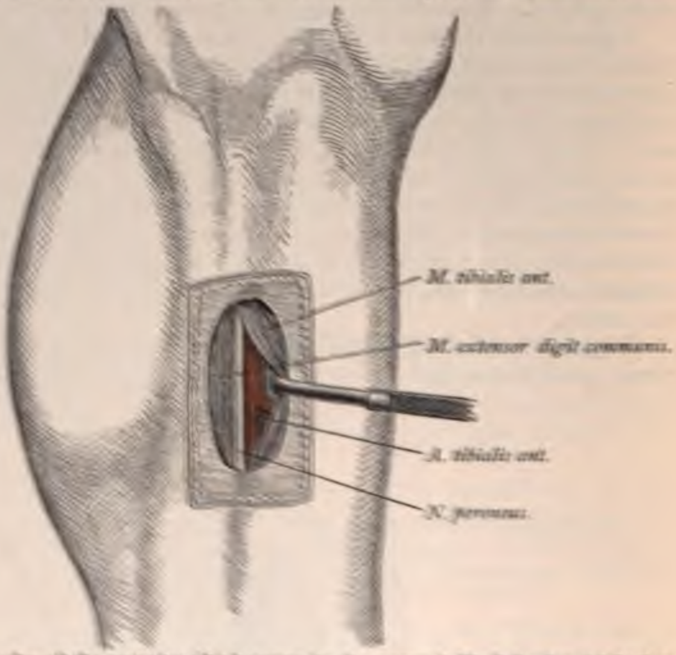


FIG. 81.—Topography of the anterior tibial artery in the upper half of the leg (right leg, viewed from the outside) (after Loebker).

tibialis anticus, on its outer side the extensor longus digitorum and extensor proprius hallucis muscles; and in the lower third it is crossed by the tendon of the latter. The anterior tibial nerve lies to the outer side, except in the lower third, where it may be in front of the artery. In the upper third an incision should be made in the line of the vessel, the deep fascia divided, and the intermuscular space found. On separating the muscles the vessel will be seen closely attached to the interosseous membrane. In the lower third the tendon of the extensor proprius hallucis is the best guide.

Ligature of the Dorsalis Pedis Artery.—The course of the dorsalis pedis, the continuation of the anterior tibial artery, is indicated by a line drawn from a point midway between the two malleoli to the interspace between the first and second metatarsal bones. It lies between the tendons of the extensor longus hallucis and the inner

tendon of the extensor communis digitorum; and in its lower part is a V-shaped space between the extensor longus hallucis and the inner fasciculus of the extensor brevis digitorum. It is covered only by the skin and superficial fascia, and rests upon the bones of the tarsus, having the internal branch of the anterior tibial nerve generally on its

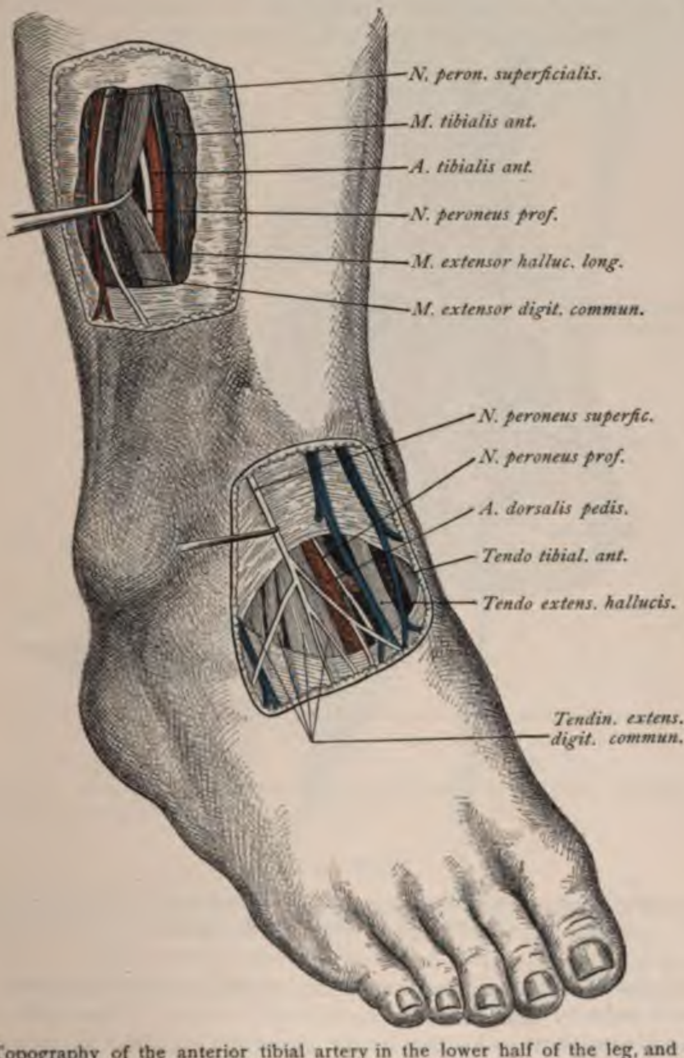


FIG. 82.—Topography of the anterior tibial artery in the lower half of the leg, and of the dorsalis pedis (after Loebker).

outer side. The incision should be made over the prominence of the instep in the line of the artery.

Ligature of the Posterior Tibial Artery.—The posterior tibial artery extends from the lower border of the popliteus muscle, at a point midway between the head of the fibula and the internal tuberosity

of the tibia, to the center of a line drawn from the tip of the internal malleolus to the prominence of the heel, thus inclining gradually to the inner side of the leg. In its upper part it is very deeply placed, being covered by the gastrocnemius and soleus and firmly bound down to the fascia covering the deep group of muscles, the tibialis posticus and the long flexor of the toes; but as it approaches the

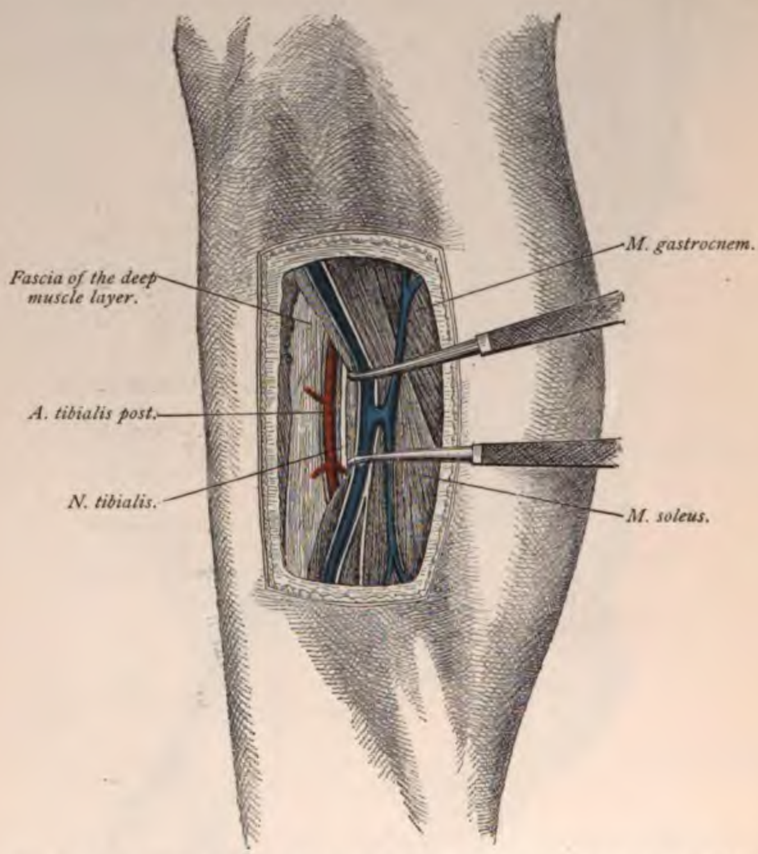


FIG. 83.—Topography of the posterior tibial artery in the middle of the leg (right leg, seen from the inside) (after Loebker).

ankle-joint it becomes much more superficial, and in the lower third is covered only by skin and fascia.

Ligature High.—In the upper two-thirds of the leg the vessel is so difficult to reach that the operation is rarely done. The leg should be flexed at a right angle, so placed that the internal aspect is readily accessible, and a free incision made a finger's breadth posterior to the inner border of the tibia. The internal head of the gastrocnemius is pushed aside, and the attachment of the soleus to the tibia divided $\frac{1}{2}$ inch from the bone. The deep intermuscular fascia will then come into view, and the muscular planes may be readily separated. The

artery will be found lying upon the tibialis posticus muscle, with the nerve to the outer side.

Ligature Low.—The artery is readily reached at the point where it passes behind the internal malleolus, having the tendons of the tibialis posticus and flexor longus digitorum between it and the malleolus, and the tendon of the flexor longus hallucis behind. At this point the nerve generally lies posterior to the artery; but it may have divided above this point, when the artery will be found between the

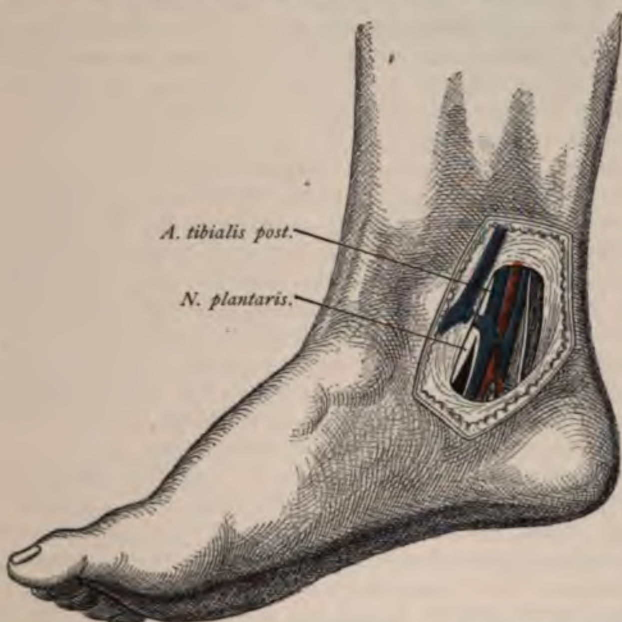


FIG. 84.—Topography of the posterior tibial artery in the region of the ankle-joint (after Loebker).

two branches. A curved incision, a finger's breadth behind the internal malleolus, will readily expose the vessel.

AMPUTATIONS.

General Considerations.—This general class of operations may become necessary because of injury, disease, or malformation. For the first cause, in the conservative surgery of to-day, amputations are far less common than formerly. In the second class are included all infectious and septic cases. Operations performed immediately after the injury are said to be *primary*. If necessary later, from extension of the septic process, or to save life, they are called *intermediate*. If for improving the usefulness of the part, or for other reasons, after healing has taken place, they are called *secondary*.

Amputations are said to be *in continuity* when the bone is sawed through; *in contiguity*, when at the level of the joint the limb is disarticulated.

In these three classes of causes the success of the operation may be

said to depend upon factors that are common to all; for instance, to the shock of an operation must be added, in cases of injury, the shock of the original cause. Therefore, for an injury it is the rule to amputate as low as possible, to obtain a viable stump, even at the risk of leaving a less perfect stump, *as the shock of the amputation varies directly with the length of the part amputated.*

Shock in these cases also varies directly with the amount of hemorrhage and the duration of the operation; hence celerity, combined with due attention to hemorrhage, is an important factor. On the other hand, in malignant disease it is all-important to remove the disease entirely, with sufficient margin; and in malformation most attention must be paid to the resultant stump. In these cases it is often well to prepare the patient for operation by stimulant and tonic treatment for a few days.

The resultant **stump** is to be considered from its locality as successful, in the hand or foot, for its non-interference with other members, and somewhat for its appearance; in the arm, for the facile attachment of an artificial hand; and in the leg and thigh, primarily for their weight-bearing function, absolute insensitiveness is essential. The dangers to be avoided in the resultant stump are, in the skin, overtension, which may interfere with its nutrition; in the muscle-flap, insufficient blood-supply, which may delay healing; and in the bone, rough edges or careless laceration of the periosteum, which will give trouble in the stump by undue proliferation or necrosis. Nerves may also be caught in the scar, and be a cause of much pain.

In general, to obtain a good result, the skin-flap should be cut long enough to cover the stump without drawing tightly, without being so loose as to cause redundancy; the latter being the lesser evil, but retarding somewhat the hardening of the stump into condition to support apparatus. The scar will then be freely movable over the underlying parts, and should be out of the way of pressure; for instance, in the fingers the scar should be on the back; in the leg, it should be to one side.

The muscle-flap should closely approximate to its fellow or should itself cover the bone. Nerves should be cut short and allowed to retract: they will then be out of the way of pressure in the scar, and then, even if "bulbs" form, they will probably give no trouble. Tendons and fibrous tissue should also be cut short, for their blood-supply is never too good; and as they are likely to turn under the long amputating-knife and leave ragged edges, they should be drawn down with forceps and cut again.

The *pathological changes* which take place in the stump are represented by atrophy of the muscles and a general increase of connective tissue. Occasionally, in a child, the bone may continue to grow, and this cannot be entirely avoided; but a bad result may in a measure be prevented by sawing the bone especially short in these patients. When it occurs, a second operation is the only remedy. To ensure smooth ends to the bones the periosteum should be peeled back a short distance before sawing, and then turned over the end of the bone. The objection to this method—viz., that osteophytes may form and proliferation of the bone ensue—need not be seriously regarded.

Arteries, on the other hand, should be left long, for the double purpose of nutrition of the stump and the prevention of hemorrhage, their elasticity often drawing them back into the tissues, where the smaller ones may escape notice and give trouble later.

The necessity of drainage in the wound depends upon various conditions. Following injury, if the tissues are bruised or lacerated as far up as the field of operation, or when absolute asepsis is not certain, the wound must be drained. For this purpose, especially in the cases in which there is much bruising and likely to be outpouring of serum, a drainage-tube, preferably of rubber, is placed in the most dependent part of the skin-wound; or two are placed in opposite corners of the wound, if these are equally dependent. In cases less likely to be followed by much serous effusion, a small wick or strand of gauze may be placed in the wound, and one or two provisional sutures placed where the skin is left open. These may be tied twenty-four hours later, when the wick is removed. In other cases, when the condition of the patient is such that haste is all-important, the whole wound may be packed with gauze, with or without provisional stitches in the flaps. The gauze is removed as indicated when the wound is dry and the patient has recovered from the shock of the operation. This, of course, is not intended to apply to amputations following acute infectious processes, where the wound is necessarily left open and kept moist with antiseptics, in direct opposition to the drying and close suturing of flaps which favor rapid healing in aseptic cases.

Much of the close apposition desired is gained by a proper dressing. The stump should be placed on a straight splint which extends beyond the end of the stump, and must not be too broad, since that will cause the stump to flatten, and the pressure cannot be evenly distributed. The dressing should be not too voluminous, larger in cases with drainage than in those without it, and should be both absorbent and elastic. These qualities are combined in a dressing of absorbent gauze, with a layer of absorbent cotton, and over all sheet wadding; the whole, of course, sterilized. Bandages are applied with even pressure, tight enough to obliterate any dead space, but not so tight as to impede the circulation.

Methods of Controlling Hemorrhage.—Hemorrhage is a very important feature. Secondary hemorrhage has been a most frequent cause of fatal results; and free bleeding of small, retracted vessels results in clot-formation, which clot may break down and separate, causing healing by second intention even under careful aseptic precautions. Hemorrhage is controlled at the time of operation by various methods. The main artery supplying the part is held either by the hand of an assistant or by a tourniquet. This may be one of several patterns. It was originally a pad placed over the artery under a few turns of a bandage, which bandage was tightened by drawing over a short stick that was turned till pulsation ceased in the part below. Such a tourniquet, modified and improved, is represented in the Petit tourniquet now in common use (Fig. 85). It may consist of a steel band, with two pads where the artery is double, as at the wrist, tightened by a screw at the side; or the ordinary rubber tubing tourniquet may be applied with one or more turns. The tissues may also be ren-

dered more or less bloodless by elevation of the limb or by the application of the rubber bandage (Esmarch). This has some disadvantages in that it may drive a thrombus or septic material into the general circulation. The advantage of throwing the blood of the part into the rest of the vascular system is questionable except in cases of very low blood-pressure; and there is danger of too much vasomotor paralysis occurring as a result of the pressure of the bandage, so that when the tourniquet is removed the field of operation itself has an engorged and sluggish circulation.

FIG. 85.—Petit's tourniquet.

FIG. 86.—Square knot.

In the wound itself each vessel, as seen, should be secured with a ligature of the selected material, tied firmly but not too tightly. Ballance and Edmunds have shown conclusively that to occlude an artery it is not necessary to rupture any of the coats, and that the danger of secondary hemorrhage is even less where the coats are left intact. A broad ligature, ensuring apposition of the intima for a certain distance, is best—either an animal tendon, chromic catgut, or silk. Having secured all the larger vessels, the wound is sponged dry and the tourniquet loosened gradually. As the smaller vessels reveal themselves, they in turn are picked up and tied. General oozing is treated by a thorough flushing with a hot saline solution or with very dilute antiseptics, after which the wound is sponged dry and closed. Frequently, in the minor amputations, very little tying is necessary, bleeding being entirely controlled by a few minutes' pressure by either the sponge or the pressure-forceps. If tied, care must be taken that the ligature is far enough from the end of the vessel not to slip off, and that the first hitch does not slip—that is, become loosened. The second hitch, taken in the opposite direction, completes the "reef or square knot," as illustrated in Fig. 86. Some surgeons prefer to make the first a "surgeon's knot," which is simply an extra turn on the thread. This does not slip, but has the disadvantage of not pulling up smoothly, and it is difficult to estimate the amount of force required. If a second hitch is made over it, the knot is too thick. Without the second hitch it is not reliable. Serious and even fatal hemorrhages have followed its use. The last precaution is taken with the closing of the wound and the application of pressure-dressing.

The **preparation for an amputation** consists in the aseptic and antiseptic precautions described in the preceding chapter, the preparing of a splint and dressing as given, and the lay-out of the *instruments* as given below: An amputating-knife, and, if desired, a smaller blade for

FIG. 87.—Amputation-knives for ordinary use.

dissection of the skin-flap. If there are two bones in the amputation, as in the forearm and leg, then the catlin, with both edges sharpened, is necessary; also scissors, toothed dissecting-forceps and artery-forceps, compression or hemostatic forceps, bone-cutting forceps for trimming rough edges, if necessary, or for cutting the bone itself; but too large bones or edges must not be cut with these, as splintering occurs. Lion-

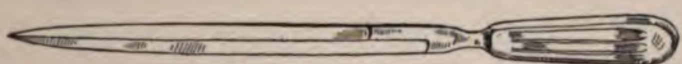


FIG. 88.—Catlin amputating-knife.

jawed forceps are of use in holding or manipulating the bone, especially in amputations in contiguity. Retractors of various patterns may be used, or spatulæ; but generally two gauze strips crossed, with a third between the bones if there are to be two, afford most efficient retraction. There should be a periosteum-elevator; and last, the saw, which should be strong, with closely set teeth. In addition to these, there must be needles with sutures, and ligatures of the selected material; and drainage-tubes, if these are to be used.

Methods of Amputating.—Operations may be divided into two general classes—the *skin-flap* and the *muscle-flap*. These are subdivided into circular and oval methods. These classes are not generally recognized, but seem to be clearly distinguished, as the circular method, described by all authors, is done under the one class or the other independently. For instance, in the thigh the knife sweeps first through the skin (which is retracted); second, through the superficial muscles, these in turn being retracted; three or four sweeps reach the bone, which is then sawed through, and is found to be the apex of a cone-shaped wound, the sides of which, when closed, approximate the cut surfaces of the muscle to each other, while the fascia and skin come together over all. Properly speaking, this is a muscle-flap operation. But, on the other hand, in the forearm the circular cut is made through the skin alone, which is then dissected back, and the muscles are cut directly through to the bones, which are sawed high in the wound. The skin is closed directly over the cut muscle-edges. This is a skin-flap operation.

The Circular Method.—The surgeon should stand beside the patient, so that his left hand may grasp the limb to be operated

upon on the proximal side of the line of amputation. While the part to be amputated is held by an assistant, another draws the skin-tissues firmly upward. The incision is begun at the top, the surgeon's arm being passed under and to the further side of the limb, and the knife held point upward, with the blade toward him. A single slow sweep of the knife carries the incision through the skin and subcutaneous tissues to the muscle-fascia, completely around the part, ending at the starting-point. The skin is then dissected back a short distance, and a second sweep of the knife in the same manner cuts the superficial muscles; while these are held retracted a third cut completes the incision to the bone. With a periosteum-elevator the periosteum is stripped back from the cut which the last sweep of the knife has made, and the saw is applied $\frac{1}{4}$ to $\frac{1}{2}$ inch higher. The sawing should be done slowly at first, to avoid jumping of the saw, and very slowly just before the bone is cut through, to avoid splintering. The left arm of the surgeon will naturally be held in a line parallel with the working of the saw, and the assistant who is holding the part should also have his arm parallel, not at right angles, as he can then firmly resist the thrust of the saw. To prevent the bone binding the saw in the cut, the bone should also be held somewhat against the saw, but without force, or the bone will be broken and splintered before the saw cuts through. If there are two bones to be sawed through, the saw should be applied to the larger first; and when a groove is made, the smaller bone is cut through, the saw running in this groove as a guide. Finally, the larger bone is cut through. Any sharp edges are trimmed with the cutting-forceps, the periosteum drawn forward over the end of the bone, and the wound closed.

The Method by Circular Skin-flap.—The above description applies to this method, save that the skin is dissected a little further back, and the muscle-incision is carried at once to the bone.

The Oval Method.—Where, for any reason, it is desired that the scar shall not be terminal, it may be made lateral by one of the oval methods, which may be either of muscle or of skin-flap. The muscle-flap operation may be done by transfixion or from the outside. Transfixion is the method of surgeons of earlier days, and belongs to times when brilliancy and speed were accounted of most value. There is much, however, to be said for it, as with a thin but sufficiently rigid knife, 1 or 2 inches longer than the diameter of the limb, a beautifully clean cut can be made. The knife is thrust directly through the limb, at the level where the bone is to be sawed, and passes just over the bone at this point, and out at the other side, the cutting-edge facing toward the extremity. It is then brought directly out through all opposing tissues to the point on the surface where the lowest part of the long flap is designed to be. This flap is turned back, the bone sawed, and the muscles and skin cut straight through to the opposite side. The line of scar will then be on the side opposite the long flap. Variations of this method have received special names, as the *long anterior flap operation*, and the *rectangular flap* or the *lateral flap*.

To accomplish this result as to the location of the scar in the class of skin-flap operations, similar incisions are made through the skin alone. In the oval incision the scalpel starts on one side and passes

obliquely downward and across, is transverse on the opposite side, and comes obliquely upward and across to the starting-point. The most frequent variation of this is the so-called *racket method*, which has a straight vertical incision at the start, is oblique on the sides, and opposite to the beginning of the incision. It is much used in amputations at the metacarpophalangeal joints, having the advantages of neatness and bringing the scar entirely out of the grasping surface of the hand.

Another modification of this is to cut two oval flaps, equal or unequal in length, the advantage of which is the avoidance of the corners which are present in the circular flap operation, and the bringing together of the skin smoothly, with even pressure, over the rounded stump.

Amputation of the Fingers.—Because, in the majority of cases, amputation of a finger is necessitated by trauma, the surgeon often has to adapt his methods to the case. When possible, however, a long flap should be taken from

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Amputation of the Fingers.—Because, in the majority of cases, amputation of a finger is necessitated by trauma, the surgeon often has to adapt his methods to the case. When possible, however, a long flap should be taken from the palmar surface, in order that the most sensitive skin shall be at the end and the cicatrix on the dorsal surface. It is of prime importance to save every possible part of the hand or finger (except in malignant disease), as no apparatus can ever compensate, and the most unpromising stumps are of use. In amputating through a joint, the finger should be flexed, the joint opened, a long palmar flap made by keeping the knife close to the under surface of the distal bone, and the flap turned over to meet a short dorsal one, thus bringing the scar on the back. The same flaps should be made when amputating through a phalanx. The vessels are on either side of the finger, and bleeding may be controlled by pressure or sutures.

Amputation through the Metacarpophalangeal Articulations.—In the removal of an entire finger, an incision should be made about $\frac{1}{2}$ inch above the joint on the dorsal surface, and carried around the finger to a point $\frac{3}{4}$ inch from the web on the palmar surface; and a similar incision should be made on the other side of the finger to meet it. The soft structures are then divided, the finger removed, and the flaps trimmed and brought together.

The incisions should be modified for each finger, in order to bring the resulting scar as far from the palmar surface as possible. The thumb may be treated as a phalanx, and a long palmar flap used; or the incision known as Malgaigne's racket may be made, which is somewhat of a Y shape, the handle being on the dorsal surface. Several fingers may be removed at once, although it is advised to remove each separately by the most suitable incision (Matas). Hemorrhage can be controlled by ligatures or pressure (Fig. 89).

Amputation of the Metacarpal Bones.—The removal of a metacarpal bone along with the finger is an operation not often done. The usual way is to remove the finger with part of the metacarpal, which is a much simpler procedure. However, it is sometimes necessary to remove the first or fifth metacarpal entire. This is attended with less difficulty and danger, as their synovial sacs do not communicate with the others, and thus danger of infection of the wrist-joint does not occur. The same incision is used as for amputation at the metacarpophalangeal joint, the dorsal incision being carried far enough up to

expose the bone (Malgaigne's racket) (Fig. 90). The soft parts are carefully separated, and the bone cut with forceps or disarticulated, as the case may be. Great care must be taken not to injure the palmar arch, which crosses on the palmar side of the bones near to the proximal ends. In removing the first metacarpal, the operator should remember the relation of the radial artery, which passes around its

FIG. 89.—Dorsal view of hand. Exarticulation of the fingers by racket incisions: *b*, exarticulation of the thumb by flap incision; *a a*, exarticulation of the hand by long dorsal flap.

FIG. 90.—Hand, view from dorsal side: *a*, exarticulation of the index finger at the carpometacarpal joint with racket incision; *b*, exarticulation of the third and fourth metacarpal bones with oval incision; *c*, exarticulation of the fifth metacarpal bone with flap incision.

ulnar side. The fifth metacarpal is more accessible from a lateral incision.

Amputation of the Wrist.—Circular Method (Fig. 91).—In this method the surgeon makes a circular incision about the wrist, beginning on the radial side. The incision should begin about ½ inch below the styloid process of the ulna, and incline somewhat lower toward the radial side, as the styloid process of the radius is the longer.

The skin is then dissected off and reflected back as a cuff, both styloids being exposed. The hand is sharply flexed, and the soft parts divided, beginning at the radial side, with the external lateral ligament and extensor tendons, then the internal lateral ligament and anterior ligament, finally coming through the joint and cutting the flexor tendons last. The vessels are the radial, the ulna, and the anterior interosseous.

Anteroposterior Flaps.—Here two equal flaps are made, one from each surface. For the dorsal flap a curved incision from one styloid

to the other is made, a similar one being cut from the palmar surface. The flaps are turned back and the soft parts divided. Amputation with the long palmar flap needs little explanation. It is a modification of the other method. The palmar flap extends from just below the styloids to the middle of the metacarpal bones in a U shape (Fig. 91, *b*), the dorsal incision being a straight cut over the articulation, joining the two ends of the U.

External Lateral Flap.—This is known as Dubrueil's[1] operation, and may be briefly described as follows: The incision is begun at the back of the wrist, at the junction of the outer and middle thirds, and ¼ inch below the line of the wrist-joint, is carried downward toward the thumb, and, crossing the first metacarpal bone at its middle, returns to a point on the palmar surface opposite its starting-place. Dissecting

FIG. 91.—Palmar view of hand, showing circular method (*a b*); long palmar flap (*b*); Dubrueil's incision (*a c*).

the flap to its base, making it as thick as possible, the skin and soft parts internal to the flap are now divided by a circular cut on a level with the base of the flap. Disarticulation is thus effected, and the flap is brought transversely across and sutured (Fig. 91, *a c*).

Amputation of the Forearm.—All authorities agree that the circular method is the best for amputation of the lower third, and the flap method for the other two-thirds. In the circular method "the skin-cut is made at a distance below the future saw-line equal to the anteroposterior diameter of the limb at that line" (Treves). The soft parts, principally tendons, are best divided by transfixion from within outward. In sawing the bones it is best to saw the radius first, then the ulna, the radius being the movable bone. In the anteroposterior

[1] For full description see Chalot (*Chirurgie Operatoire*, 1886).

flap method the flaps should be marked in the skin with a knife, and after retraction has taken place two equal muscle-flaps from the anterior and posterior surfaces should be cut by transfixion (Fig. 92).

Another method, which is suitable for use in any part of the arm, is to make two curved skin-flaps and divide the other soft parts by a circular cut. The skin-flaps may be of equal length, or the posterior one somewhat the longer. Teale's method has been suggested for use in the forearm, but the flap is thin and poorly nourished. The operation is not to be recommended. The vessels are the radial, ulna, anterior and posterior interossei.

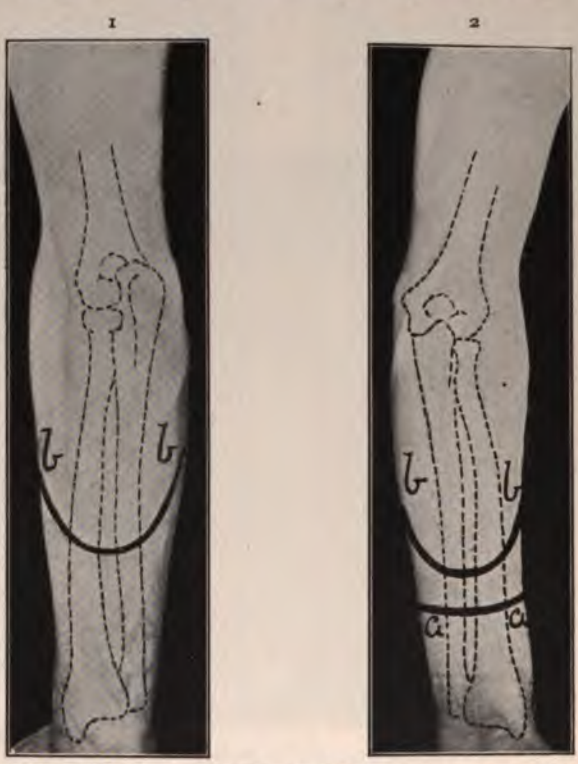

FIG. 92.—Amputation of the forearm: 1. Flap method, posterior view. 2. Flap method (*b b*); circular method (*a a*).

Amputation of the Elbow-joint.—There are several methods described for this operation: the anterior flap, the circular, the lateral flap, and the elliptical.

Anterior Flap Method.—With the arm extended and the hand in supination, an anterior skin-incision is made beginning at a point an inch below the joint on the ulnar side, extending in a long curve to about $3\frac{1}{2}$ inches from the bend of the elbow, and terminating $1\frac{3}{4}$ inches below the external condyle. This will give a U-shaped flap. The ends of the anterior cut are joined by a posterior one. Some operators prefer to do this by making a short posterior flap. After the skin has been retracted, the anterior muscle-flap is cut by transfixion and lifted

up, and any deep muscle-fibers that may be left are divided. The joint is then opened by dividing the anterior ligament, then the lateral ligaments, and the disarticulation is completed by cutting the posterior ligament and the triceps tendon (Fig. 93, *c*). The vessels are the

FIG. 93.—*a*, Amputation of the upper arm, flap method; *b*, disarticulation of the elbow; *c*, anterior flap method.

FIG. 94.—Disarticulation of the elbow: equal flaps (*e*); long external flaps (*d*).

brachial, or the radial and ulna, according as the bifurcation of the brachial is high or low.

The Lateral Flap Method.—This operation may be done with one long external flap, or an external and an internal flap. The external flap should be made by transfixion, the knife entering close to the head of the radius and emerging at the back of the joint, on a level with it, near the olecranon. The knife is carried downward, cutting a flap 4 inches long. The ends of the external incision are now joined by an internal incision. Disarticulation is effected by opening the joint from the radial side.

Amputation of the Arm (Fig. 93).—This operation may be performed by any of the recognized methods of amputation, the circular being better adapted to the lower part of the member. The tissues on the inner side of the arm have the greater power of retraction, and this is to be remembered in making a circular cut. The method which is recommended by Wyeth and others can be used on any portion of the arm. It consists of a circular skin-incision, made with a slant to

the inner side, and a short incision at right angles to it on the outer side. This enables one to make a good cuff. The muscles are divided by a circular cut to the bone, parallel to the circular skin-cut.

Amputation at the Shoulder-joint.—The greatest difficulty in amputation at the shoulder-joint lies in controlling hemorrhage; the Esmarch tourniquet, as used by Wyeth, or a preliminary ligature or digital compression of the axillary artery and vein being required. Those methods of amputation which afford the best opportunity for securing the vessels have met with the most approval, and in general provide for the completion of the greater part of the operation as well as for ready digital compression or ligature of the vessels in the flap, before their actual division.

The Oval Method (*Larrey*).—An incision is made from just below the acromion down the outer aspect of the arm, through the deltoid muscle to the bone. This incision is prolonged for about 4 inches, and, from its middle, anterior and posterior skin-incisions are made, which meet on the internal surface of the arm at the level of the lower extremity of the first incision. The anterior flap is dissected up, dividing the pectoralis major at its insertion and exposing the axillary artery. The posterior flap is dissected close to the humerus, to avoid wounding the posterior circumflex artery. Upward pressure on the elbow now puts the joint-capsule on the stretch, so that it may be divided against the head of the humerus, and rotation inward and outward allows division of the muscles in front and behind. Continued upward pressure and abduction of the humeral head permit division of the capsule and the muscular attachments below the joint. While an assistant now compresses the axillary artery in the anterior part of the wound, a single cut downward divides the vessels and joins the original oval skin-incision, completing the disarticulation.

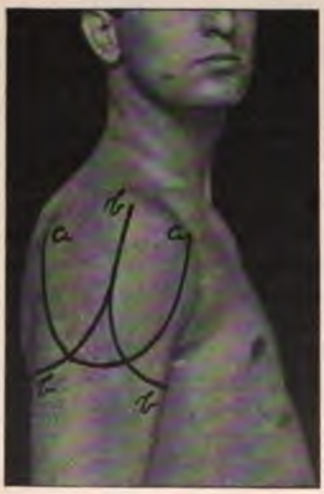

FIG. 95.—Amputation at the shoulder-joint: *a a*, large external flap; *b b*, by racket incision.

The Double Flap Method (Fig. 95).—The muscular mass of the deltoid may be used as a flap, and, whether cut by transfixion (Lisfranc) or dissected from without inward, will still permit the compression of the axillary artery in the wound before its final division. The incision will reach from the tip of the coracoid process in front, downward nearly to the insertion of the deltoid, and upward again to the base of the acromion behind. After this U-shaped flap is dissected up from the bone the joint is exposed and opened from above, the rotators divided, and the head of the humerus drawn out from the glenoid cavity to allow space enough for the fingers of the assistant to compress the vessel on the axillary side. The amputation is now completed by a downward cut from the humerus toward the chest-wall, forming a short internal flap.

Spence's Method.—This differs from Larrey's operation only in detail. The incision is started more on the anterior aspect of the arm, near the coracoid process, and extends through the insertion of the pectoralis major, then curves backward to the posterior axillary fold, across the axillary aspect of the arm, and upward to meet the other incision over the pectoral insertion. Dissection and division of the muscles inserted into the tuberosities are more readily performed by means of this incision, although the disarticulation and control of the artery are the same as in Larrey's operation. Spence's method is, furthermore, applicable particularly to cases in which a preliminary incision and examination of the joint-structures are desired before amputation is decided upon.

Wyeth's Method.—The safest and best way to control hemorrhage at the shoulder is to employ Wyeth's transfixion-pins in the same manner that they are used at the hip-joint (see Hip-joint Amputation, p. 357). One pin is introduced anteriorly into the clavicular portion of the pectoral, and brought out just above its axillary border; the other one is thrust through the deltoid behind the joint, the point being brought out about 3 inches below its entrance. The tourniquet is then wound tightly above them. The amputation may now be done without fear of the tourniquet slipping.

Amputation of the Arm, Scapula, and Part of the Clavicle (*Berger*).—The removal of the whole upper extremity requires a pre-

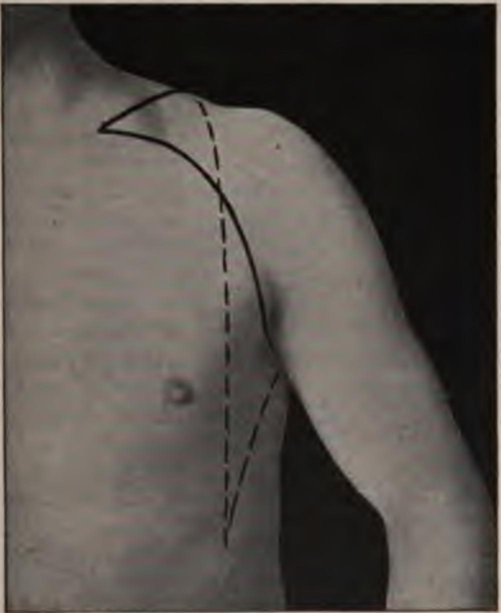

FIG. 96.—Interscapulothoracic amputation.

liminary ligature of the subclavian vessels. This is best done by the method of Berger. An incision is begun at the outer edge of the sternomastoid, and continued along the clavicle to its acromial end.

The periosteum is then divided, and the middle third of the clavicle excised by means of a chain-saw, leaving a space through which the subclavian artery and vein can be double-tied and cut. From the middle of the anterior lip of the clavicular incision the knife is passed, in an outward sweep, over the deltoid muscle to the outer end of the anterior axillary fold, across the inner aspect of the arm, and inward and downward on the trunk to the angle of the scapula. From this point an incision passes upward over the spine of the scapula to join the first clavicular incision at its outer end. These incisions at first involve only the skin; but the anterior one is now deepened, and its edge raised and dissected back, as a flap, to take in the muscular origins of the pectoralis major and minor, which are divided near their insertion. The nerve-trunks of the brachial plexus are now cut at the level of the division of the artery and vein, and the anterior attachments of the extremity are free. The latissimus dorsi is now divided by deepening the posterior incision, and upon reflecting this posterior flap toward the spine the trapezius is exposed and divided close to the scapula and clavicle. The muscles now holding the scapula to the trunk—the omohyoid, levator, serratus, and rhomboids—are divided from above downward, and the extremity is removed. The flaps come together from before backward and downward, and form a linear scar.

FIG. 97.—*a a*, Exarticulation of the great toe with dorsal and plantar flaps; *b*, exarticulation of the second toe with racket incision; *c*, exarticulation of the fourth toe with racket incision; *d*, exarticulation of the small toe with formation of an outer flap.

Amputation of the Toes.—A knowledge of the important structures in the anterior part of the foot is of the greatest importance in amputation in this region. The heads of the metatarsal bones, particularly the first and fifth, and the base of the first phalanx of the great toe, are to be preserved if possible; whereas the terminal phalanges of the other toes may best be removed in their entirety by disarticulation at the metatarsophalangeal joint. Amputation of the great toe through the first phalanx may be performed by an oval or racket incision, commencing above the web, or by a single plantar flap. Disarticulation at the metatarsophalangeal joint of the lesser toes is best performed by a racket-incision which just clears the web of the toes on its plantar surface. Much care must be taken to avoid a scar on the plantar surface, and, in the case of the great toe, to provide sufficient soft parts to cover in the bone (Fig. 97).

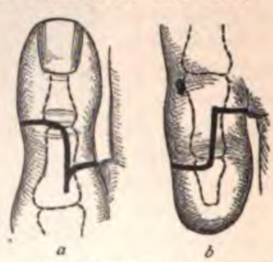

FIG. 98.—Exarticulation of the great toe with formation of an inner flap.

Disarticulation of the Great Toe at the Metatarsophalangeal Joint.—Where injury or disease of the soft parts permits, this operation

may be performed by means of a large internal flap. The incision begins at the level of the joint, and passes down on the inner side of the dorsum of the toe to the end of the first phalanx; from there it turns inward around the toe to the plantar surface, upward as far as the web, and back to the first incision at its beginning. This incision is carried down to the bone, and the flap thus formed is dissected back; the joint is opened from above, and its ligaments divided on each side and behind. The sesamoid bones are to be left in the stump, and the open tendon-sheaths closed by suture; the plantar digital vessels will require ligature. An oval or racket incision is also used for this operation, but does not provide so satisfactory a covering for the head of the bone.

Amputation of Two Adjoining Toes.—The racket-incision is susceptible of application in the removal of two or even three adjoining toes; but its beginning must be carried further on the dorsum, according to the amount of space needed for disarticulation. In the case of two toes the incision will begin in the space between the two metatarsal bones. The operation is otherwise exactly similar to amputation of a single toe.

Amputation of the Metatarsal Bones.—The bases of the metatarsal bones, which receive parts of the insertion of the tibial muscles and the peroneus longus, are of great importance to the integrity of the foot, and amputation is much to be preferred to exarticulation of the entire bone. An elongated oval or racket incision may be used, commencing where the bone is to be divided, and extending down on the dorsum, around in the digitoplantar fold, and back to its point of origin. The knife must follow the bone closely, to avoid injury to the digital arteries, and a saw is to be preferred to cutting-forceps in dividing the bone. Amputation of the first and fifth metatarsals may also be done by means of a large internal or external flap.

Disarticulation of all the Metatarsal Bones (*Lisfranc*).—Amputation of the foot at the tarsometatarsal joint was described by Lisfranc, who followed the anatomical line of separation of the bones; and by Hey, who disarticulated the outer three or four metatarsals, and separated the remaining structures with a saw. Either operation may be chosen, according to the amount of time at the disposal of the operator and the exigencies of the individual case. The large plantar flap is to be marked out first by an incision from over the prominent base of the fifth metatarsal, in a broad sweep across the sole at the heads of the metatarsals, and back to a point over the base of the first metatarsal, about 1 inch in front of the prominent tuberosity of the scaphoid (Fig. 99).

The dorsal incision, joining the two ends of the plantar flap, is cut with a gentle curve about ½ inch anterior to the articulation. The flaps each contain all the soft parts above the bone. After dissection, the joints are opened from above, beginning at the outer side, and the fifth, fourth, third, and first metatarsals are readily freed from their attachments. The second metatarsal is mortised between the tarsal bones, and requires an incision in the direction of the ankle to secure its liberation. Here *Hey's modification* may be adopted, and the saw used to complete the division of the bones, either by sawing across the base of the

second metatarsal and leaving it in position, or by dividing the internal cuneiform and taking part of it away.. The original method of Lisfranc provided for the formation of the plantar flap by cutting from within outward after separation of the joint; but a better flap will be obtained by preliminary dissection. The stump left after this amputation is a fairly serviceable one, although a tenotomy of the tendo Achillis may

FIG. 99.—Lisfranc's or Hey's amputation of the foot.

be necessary to prevent contractures due to the weakened resistance to the pull of the great muscles of the calf.

Chopart's Amputation (*Amputation through the Mediotarsal Joint*). —An incision is made on the plantar surface of the foot from just behind the tuberosity of the scaphoid on the inner side, down and across the sole at the middle of the metatarsal bones, and back to a

FIG. 100.—Chopart's amputation of the foot, internal view.

point about 1 inch posterior to the base of the fifth metatarsal on the outer side. The two ends of this incision are then united by a curved incision across the dorsum of the foot, reaching at its lowest point to the level of the bases of the metatarsal bones (Figs. 100 and 101). These two flaps are dissected up, with all the muscles and tendons, as far as the mediotarsal joint. The astragaloscaphoid and calcaneo-cuboid joints are now opened on their dorsal aspect, while the foot is held in strong plantar flexion, and the strong calcaneoscaphoid ligament is divided by cutting outward and forward from the astragalo-

scaphoid articulation. The classical operation demands the removal of the scaphoid; but a serviceable stump will be found practicable in many cases by carrying the incision between the scaphoid and cuneiforms, and thus saving part of the tibialis posticus attachment. The divided anterior tendons can be sutured to the dorsal fasciæ, and will exert some slight action in opposing the pull of the soleus and gastrocnemius; but a contraction is more than likely to occur with elevation of the heel, and tenotomy of the Achilles tendon is frequently required. The dorsalis pedis artery anteriorly, and the two plantar arteries in the sole, will require ligature. The end-result of this amputation is, as a rule,

FIG. 101.—Chopart's amputation of the foot, external view.

a satisfactory one, and with suitable apparatus no disability is to be expected (Figs. 100 and 101).

Syme's Amputation (*Tibiotarsal*).—This operation for removal of the foot at the ankle-joint is partly superseded at present by more con-

FIG. 102.—Syme's amputation of the foot, external view.

servative operations, such as Pirogoff's; but where for any reason the operations described below are impossible, that of Syme will be found to give a serviceable stump. An incision is begun at the tip of the external malleolus on its posterior aspect, and carried perpendicularly around the foot under the heel to a point just below the internal malleolus. This incision is carried down to the bone, and its ends united by a transverse incision across the front of the ankle-joint (Figs. 102

and 103). The capsule of the joint is opened, and its lateral ligaments then divided from within outward on each side. The heel-flap is now dissected free from the os calcis, the knife being directed close to the bone to avoid injury to the smaller vessels which supply the flap. The soft parts are now retracted, to allow the sawing off of the lower extremity of the tibia and the two malleoli. There is great danger of injury to the calcaneal branches in dissecting the os calcis; and the difficulties of this part of the operation will be much increased by a too generous allowance in carrying the preliminary incision forward of the perpendicular in the first place. The large pocket left in the heel-flap by removal of the os calcis is best drained by a special incision at its lowest part, and the insertion of a gauze wick or rubber drainage-tube. The anterior tibial and external and internal plantar are the important arteries. The chief objections to this operation are the difficulty in dissecting the closely adherent skin from the os calcis, the poor nourishment of the flap, and the unfavorable conditions for pri-

FIG. 103.—Syme's amputation of the foot, internal view.

mary union afforded by the dead space in the hollow heel-cap (Figs. 102, 103).

Amputation by Single Internal Flap (*Roux*).—This incision for disarticulation of the foot at the ankle-joint is applicable in cases of injury to the tissues of the heel so severe as to prevent their utilization for a Syme or a Pirogoff amputation. The incision begins at the tip of the external malleolus, crosses the dorsum with a gentle curve to a point over the scaphoid tuberosity, and reaches the middle line of the sole of the foot under the line of the internal malleolus. From this point it passes over the tip of the heel to the outer side of the Achilles tendon and back to its starting-point. The disarticulation follows as in Syme's operation, and the soft parts may be cut from within outward, freeing the os calcis and forming the flap. The articular surfaces of the tibia and fibula are then sawed through and removed, together with the malleoli.

Pirogoff's Amputation.—This operation is much to be preferred to Syme's when neither injury nor disease of the os calcis is present, being much simpler in execution, less liable to the pocketing of secretions, and giving a longer stump with a better bearing surface. Many modifications of the original Pirogoff amputation have been suggested, and some variation must be allowed for individual cases. The incisions for the Pirogoff amputation are as follows: From the point of the internal malleolus downward and across the sole to a point in front of the tip of the external malleolus, the incision being at right angles to the long

axis of the foot. Another incision joins the two ends of the first one across the front of the ankle just below the joint. After preliminary retraction of the skin, these incisions are carried through the soft parts of the bone. The joint is now opened anteriorly, the strong lateral

FIG. 104.—Pirogoff's amputation of the foot, external view.

ligaments divided as in Syme's amputation, and the posterior ligament cut through. The foot is now carried into strong plantar flexion, and the saw placed upon the upper surface of the os calcis, behind the astragalus. The saw-cut follows the line of the first incision, removing all of the foot but the posterior part of the os calcis embedded in the tissues of the heel. The malleoli and the articular surface of the tibia

FIG. 105.—Pirogoff's amputation of the foot, internal view.

are now sawed off, and the two sawed surfaces of tibia and os calcis brought together and held with sutures (Fig. 106).

The modifications in the line of the saw-cuts have been made with the view to bringing the bearing surface of the stump more on the thick sole and less on the thin surface at the back of the heel. To this end, the first incision may be carried as far forward as the calcaneo-cuboid articulation, and the saw-cut made to come out just posterior to the articulating surface. More may also be taken from the front than from the back of the tibia, with the same result, causing less rotation of

the heel-flap (Sédillot). The os calcis may also be sawed in a horizontal direction, and disarticulated in front from the cuboid to complete its removal (Le Fort). Tenotomy of the Achilles tendon is practically

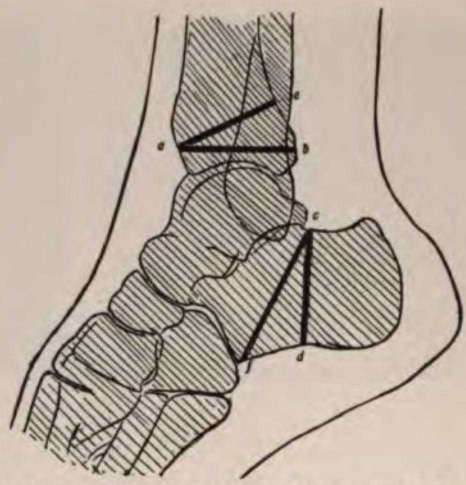

FIG. 106.—Lines of bone-cuts in Pirogoff's amputation of the foot.

always necessary in Pirogoff's amputation, and may be performed as a preliminary step.

Amputation of the Leg.—Lower Third.—*Circular and Modified Circular Methods.*—The place at which the bones are to be divided is determined, and at a point at a distance below this equal to two-thirds of the diameter of the leg a circular incision is carried around the leg, dividing the skin and subcutaneous tissue. This circular flap is dissected up and rolled back upon itself to the desired height, and another circular incision carried through all the soft parts to the bone. The catlin is now used to divide the interosseous membrane and the remaining muscular attachments, and the bones are sawed. A modification of this amputation consists in the addition of a longitudinal incision upward on the anterior surface of the flap, to facilitate dissection (Fig. 107, *a a*).

Amputation by a Long Anterior Flap.—The incision begins on the level at which the bones are to be divided, at the internal surface of the tibia, and passes downward in a curve across the anterior surface and upward to a point in front of the fibula, cutting a flap equal in length to the diameter of the leg. This flap includes all the muscles to the bone. The posterior incision is made, connecting the ends of the anterior one, and passes directly inward to the bone. The bones are now sawed at the highest point, and the flap sutured over the ends, giving a scar on the posterior surface. In sawing the bones, the saw-cut must begin in the tibia, but be made to engage the fibula as soon as a groove is cut. A double cut is also recommended, dividing the fibula slightly above the tibia; and much care must be exercised that the prominent anterior edge of the tibia be smoothed off, to prevent injury to the flap and an uneven bearing surface (Fig. 109, *a*).

Guyon's Amputation (*Elliptical Posterior Flap*) (Fig. 109, *b*).—This operation resembles Syme's amputation, and is, in fact, a supramalleolar amputation of the ankle. The incision begins 1 inch above the front of the articular surface of the tibia, and extends in a curve in front of the malleolus, on each side, to just below the point of insertion of the Achilles tendon, making a large ellipse. The flap is dissected up, containing the tendo Achillis and all the soft parts to the bone, great care being taken of all the vessels back of the ankle-joint. The malleoli and articular surface are then sawed off, as in Syme's operation, but about 1½ to 2 inches above the joint. The anterior and posterior tibial and peroneal arteries will require ligature, and the stump can be closed, bringing the scar anteriorly, and forming a good bearing surface out of the heel-flap under the ends of the bones.

FIG. 107.—*a*, Amputation of the leg at the "place of choice" by circular incision; *b*, amputation of the leg with formation of two flaps; *c c*, supramalleolar amputation.

Middle Third of the Leg.—*Long Anterior Flap.*—At a point 1 inch below the level at which the bones are to be divided an anterior flap is cut, equal in breadth and length to the diameter of the limb. The two ends of this incision are then joined by a short posterior flap cut by transfixion behind the bone (Fig. 109, *a*).

Long Posterior Flap (*Hey-Lee*).—The difficulty in this amputation is in reducing the mass of calf-muscles sufficiently to avoid an unwieldy flap. The incisions are just the reverse of those for an anterior flap, but the deep muscles of the calf are removed by dividing them circularly at the level of the saw-cut. The bones are sawed in the same manner as in the lower third of the leg, with oblique division of the crest of the tibia. The scar should lie anteriorly, but may be drawn to the end of the stump by the contraction of the muscles of the calf.

Circular Amputation with Skin-flaps (Fig. 107, *b b*).—The modification of the circular method which is best suited to amputation in the middle of the leg is that by two equal lateral skin-flaps. These flaps are each equal in length to one-half the diameter of the leg, and are marked out, beginning at a level 1 inch lower than that at which the bones are to be divided. The knife is carried through the skin and subcutaneous tissues to the fascia, and the flaps thus formed are dissected upward to their point of union. The whole flap is then dissected back to above the level of the saw-cut. The muscles and soft parts are now divided as high up as possible by circular sweeps of the knife down to the bone. The interosseous ligament is perforated, and the remaining shreds of muscle severed with the catlin. A periosteal elevator is used to push back the periosteum on the tibia and fibula and lay the bone bare for the saw. In sawing the bones in this situation the suggestion given above in regard to removing the prominent

crest of the tibia is not to be neglected, and a smooth surface free from splinters and projecting fragments must be obtained. Three arteries will require ligature—the anterior and posterior tibial and peroneal—

FIG. 108.—Amputation of the lower leg: *a*, modified circular; *b*, modified flap operation.

FIG. 109.—Amputation of the lower leg: *a*, long anterior flap; *b*, supramalleolar; *c*, Sédillot's incision.

and the flaps may then be united from before backward to form a scar at the outer side of the tibia.

Upper Third of the Leg.—Amputation at the place of election was practised extensively before the modern artificial leg had been developed, because a short stump was less in the way than a long one, when the knee was bent to fit the peg leg then in use. Amputations at this point are still performed, however, when injury or disease forbids a more conservative operation, and the circular method or one of the following flap-operations may be adopted (Fig. 107, *a a*).

Modified Flap Operation of Bell.—Two equal flaps are marked out upon the skin, each being, after retraction, about equal in length to one-half the diameter of the leg, their bases being at the level of

the intended division of the bone, the incision starting in front at the inner border of the tibia, and behind at a point diametrically opposite. These flaps include the skin and subcutaneous tissue, and are dissected back beyond their point of union. The muscles are divided in the manner of the circular operation, the knife being carried a little higher in front than behind. The bones are then sawed through, and the vessels tied in the usual manner.

Large External Flap (Fig. 109, *c*).—This amputation may be performed by transfixion (Sédillot), or the flap may be dissected from without inward (Faraboeuf). The flap begins at the level at which the bones are to be divided. The knife enters over the anterior surface of the tibia, marks out a long U-shaped flap, upon the external surface, equal in length to the diameter of the leg, and ends at a point opposite to its point of entrance. This flap is dissected up, and contains all of the soft parts above the bone. The short posterior flap may be cut either by transfixion or dissected from without inward, and the two flaps retracted to allow division of the interosseous membrane and the application of the saw. The fibula may be sawed a little higher than the tibia in all of the amputations in this region, in order to provide a more evenly shaped stump, and the crest of the tibia is to be removed as a matter of routine. After ligature of the three main vessels the external flap is brought over the end of the bone and united to the shorter internal flap, giving the scar to the inner side of the stump. This is considered by many surgeons to be the best method for amputation in this region.

Amputation in the Lower Third.—This is attended by much less shock than are amputations above this point, and is much to be preferred when the nature of the injury or disease does not forbid. The selection of a method in all amputations of the leg must depend upon the personal choice and practice of the surgeon and the demands of the individual case. As a general rule, the circular method, or one of its modifications, will be found most universally applicable, and the operation by far the most easy of execution.

Amputation at the Knee.—Disarticulation.—*Long Anterior Flap* (Fig. 110, *a*).—An incision is begun at the posterior and inferior margin of the femoral condyle, and is carried downward, across the front of the tibia, 5 inches below the patella, and back to the corresponding point on the other side. This flap includes skin and subcutaneous tissue up to the ligamentum patellæ, which is then divided and left in the flap. The joint is opened, its ligaments divided, and the amputation completed by an incision from within outward to the posterior surface of the limb (Fig. 110).

Lateral Flaps (*Stephen Smith*).—Two equal lateral skin-flaps are cut, their bases extending posteriorly to the middle line of the joint, and anteriorly to 1 inch below the tubercle of the tibia. Each of these flaps is dissected up, and the joint is opened and its ligaments divided from in front. The posterior ligaments and muscles are then cut through and the disarticulation is complete. The patella and the semilunar cartilages should remain in the stump. This method gives an excellent bearing surface for the stump, the scar retracting between the condyles of the femur.

Amputation Through the Condyles.—*Oval Method.*—This incision is practicable either for disarticulation (Baudens) or for amputation through the condyles. An oval cut is made around the leg, 3 inches below the patella in front, and on a level with its lower border behind. The skin and subcutaneous tissues are dissected up as in the circular operation, and either disarticulation is performed as already described, or the bone is sawed above the articular surface. The patella may be left in the anterior part of the flap, or it may be dissected out and removed with the tibia.

Carden's Amputation (*Anterior Flap*) (Fig. 110, *b*).—An incision begins over the posterior portion of the femoral condyle 1 inch above the joint, and extends in a broad sweep across the front of the knee, about half-way down the ligamentum patellæ, and up again to a point on the other side corresponding to its point of origin. This incision extends through skin and subcutaneous tissue only, and the flap is dissected up to above the patella. The two ends of the first incision are now united by a short curved incision across the back of the joint. After retracting the anterior flap, the quadriceps tendon is divided, the joint opened and disarticulated, and the posterior muscles severed from within outward. The articular surface of the femur is now sawed off, and the operation is completed by ligature of the popliteal artery and its articular branches, and suture of the wound from before backward.

Gritti's Amputation (Fig. 111).—By this method the patella is used to cap the stump of the femur, and advantage is taken of the prepatellar bursa to provide a loosely moving covering to the end of the stump. The general steps are the same as in Carden's operation, the long anterior flap being more rectangular and its base slightly higher on the front of the femur. The anterior flap is dissected up, and the ligamentum patellæ divided at its insertion and retained in the flap. Disarticulation follows as in Carden's operation, and the articular surface and condyles of the femur are sawed through at a level above their most prominent part. The sawing of the patella is the most difficult part of this operation, and is best accomplished by a small metacarpal saw while the bone is held firmly with lion-forceps. After the articular surface has been removed and the necessary blood-vessels tied, the patella is drawn down over the end of the femur and held with pins or sutures. This operation is an imitation of Pirogoff's osteoplastic ankle-amputation, but does not appear to have attained the popularity of Pirogoff's, although not essentially differing from it in any way. The technical difficulties, however, in its performance are considerable, and a tendency has been noted to the drawing forward and upward and displacing of the patella by the strong quadriceps muscle. This may be obviated by a sufficiently high division of the femur, or by section of the quadriceps tendon in whole or in part.

Amputation of the Thigh.—Here the conditions are similar to those in the upper arm, there being one bone well surrounded by muscle, except at the lower end, so that almost any recognized method of amputation may be carried out. There are many operations, differing slightly, described by and named after different men. None will be mentioned except those commonly used. Amputation may be per-

formed anywhere from the trochanter to the condyles, but is generally done at some part of the middle third. The operations consist of the flap and the circular methods, with a modification of each. As the skin and muscles on the posterior and inner side have the greater power of retraction, the operator must correct this by making his incision lower at these points. The number and size of the vessels to

FIG. 110.—Disarticulation of knee: *aa*, long flap; *bb*, after Gritti and Carden.

FIG. 111.—External lateral view of thigh: *a*, Gritti's incision for disarticulation of knee; *bb*, Sédillot's amputation of thigh; *c*, double flap method in lower third; *dd*, external racket incision for hip-joint.

be tied will vary with the height of the section. They include the femoral, profunda, anastomotica magna, perforating and muscular branches.

Flap Operations.—In the anteroposterior method the flaps are made by transfixion, the posterior being the longer, to allow for the greater retraction which takes place. The main artery will be in the anterior or posterior flap according as the section is high or low. In the lateral flap operation (Vermale) the flaps are also cut by trans-

fixion and are of equal length. This operation is not much done at present, and is not a good one for the lower part of the thigh.

Long Anterior Flaps (Fig. 111, *c*).—This method gives very good results. The flaps are marked out first on the skin as follows: An anterior flap is cut, with its base about half the circumference of the limb, and its "length equal to one diameter and a half of the limb at the saw-line" (Treves). A short posterior flap is also marked out. In this case the anterior flap is best cut from without inward, following the line in the skin, taking care that it be not too thick. The posterior flap may be cut by transfixion. The bone is then exposed and sawed through. In sawing through the femur, in all cases the edges should be smoothed by bevelling with a saw or chisel.

The modification known as *Sédillot's operation* differs from this in that there is no posterior flap, the structures being cut straight to the bone (Fig. 111, *b*).

The Modified Circular (Fig. 112).—An oblique circular incision is made in the skin, beginning at the outside of the thigh, and carried

FIG. 112.—Amputation of the thigh with oval incision.

inward about the limb to the starting-point, with a downward slant sufficient to allow for the posterior retraction. According to Faraboeuf, the incision on the anterior surface should be at a distance from the proposed section equal to one-quarter the circumference of the thigh at that point, and that on the posterior equal to about one-third of the same. The skin is loosened and held back evenly. The muscles are then divided obliquely in layers parallel to the skin-incision, each layer being allowed to retract. The muscles are then held back and the bone is sawed.

Another very excellent method, described by Wyeth, consists of an oblique circular skin-incision with a short incision on the outer surface at right angles to the first, which is practically a racket incision with a short handle. This enables the operator to turn the skin back with greater ease. The rest of the operation is the same.

In Syme's modification two extra incisions are made, thus forming short rectangular anterior and posterior skin-flaps.

Amputation at the Hip-joint.—This operation is by far the most formidable of all the amputations, and was for a long time deemed unjustifiable; but modern technic has brought it under the

head of recognized operations, and it may be done successfully in many cases. It is indicated when amputation cannot be done below the great trochanter. The principal dangers are hemorrhage and shock, the latter being somewhat dependent upon the former. The prevention of shock is elsewhere considered. There have been many means suggested for the control of hemorrhage: manually, by digital compression of the aorta, the external iliac, the common iliac (by incision), and the femoral; mechanically, by means of various apparatus, as Lister's aortic tourniquet, which is not now used, and by Davy's ingenious but unreliable method of applying pressure to the common iliac by means of a lever introduced into the rectum. Some operators prefer to ligate the femoral or common iliac first, or to tie each vessel as it appears in the wound. As the most troublesome bleeding comes from the branches of the internal iliac, some means should be adopted that will occlude them. The elastic tourniquet is the best mechanical aid we have for this purpose. The most satisfactory application is after the method of Wyeth or Trendelenburg, who first transfix the thigh with steel pins, Wyeth making use of two, and Trendelenburg one. The tourniquet is then tightly applied above them, and cannot slip.

The Esmarch elastic bandage should be applied in all possible cases, with the limb in an elevated position. The conditions contra-indicating its use are: sepsis, when some of the infected material might be forced into the sound portion of the limb; certain tumors which would obstruct mechanically; and in cases of extreme crush with pulpefaction following any severe accident.

The Anterior Racket or Oval Method (Fig. 114, *c c*).—In this procedure hemorrhage is dealt with by ligaturing the femoral first, and the other vessels as they are met with during the removal of the limb. No tourniquet is used, but the elastic bandage of Esmarch should be applied. A racket incision is made in the skin, down to the muscles, as follows: The straight part of the incision begins just below Poupart's ligament, over the origin of the femoral, and follows the course of that vessel for about 3 inches. The cut then curves obliquely inward and downward, passing about the limb, and being brought up on the outer surface just below the great trochanter, upward, to meet itself at the point of separation from the vertical incision. The next step is the ligation of the great vessels. They are exposed, the artery and vein being separately tied in two places and divided. Now the section of the muscles should begin. In the outer flap are the sartorius, rectus, and tensor vaginæ femoris. These are divided; then the gluteus maximus. Under this is found the trochanter. The limb is rotated inward to put the short rotators on the stretch, and the latter then divided. Now the thigh is rotated outward, and the psoas and all muscles on the inner side are cut. The articulation can now be opened, and the femur disarticulated by going backward through the joint and dividing the muscles at the posterior part.

The Modified Oval or External Racket Incision.—The skin-incision is made on the outer aspect of the limb; the straight portion is begun about 2 inches above the trochanter and continued downward 6 or 7 inches. It is then carried obliquely downward across the anterior sur-

face, transversely across the inner, some distance below the end of the straight incision, and upward on the posterior surface to the lower end of the first cut (Fig. 113). The skin is now loosened all around and held back; the anterior muscles being cut, all the muscles are freed from the trochanter and the upper end of the femur. The capsule of the joint is cut and the head disarticulated outward. The adductors and other muscles on the inner side are divided and the operation completed. All vessels are then tied.

The *Furneaux-Jordan method* is a modification of this one. The operation as described by him consists of a straight incision over the trochanter, connecting with a circular one at some lower level. The

FIG. 113.—Disarticulation at the hip-joint with external racket incision.

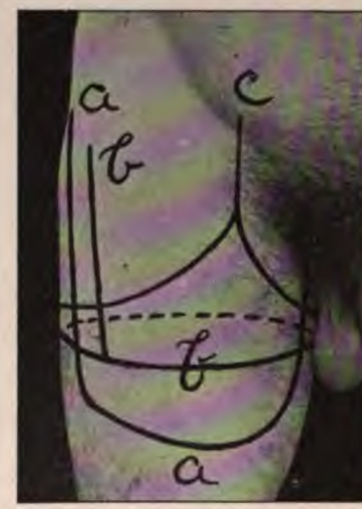

FIG. 114.—Amputation at the hip-joint: *a a*, by anterior flap; *b b*, modified circular method (Furneaux-Jordan); *c*, anterior racket incision.

bone is enucleated, and the limb removed by a circular division of the muscles (Fig. 114, *b b*).

The Anterior Flap Method.—This is the operation by transfixion, and was much used in pre-anesthetic days because of the extreme rapidity with which it could be performed. It is still done after certain cases of injury, for the same reason. The femoral is controlled by direct pressure by an assistant. To cut the anterior flap, the thigh should be flexed, and a long knife introduced half-way between the anterior superior spine of the ilium and the great trochanter, passed inward in front of the joint, opening the capsule if possible, to emerge on the inner side an inch below and anterior to the tuberosity of the ischium (Fig. 114, *a a*). A flap is now cut from within outward and turned back, the femur being disarticulated by enlarging the opening in the capsule and depressing the knee. The thigh is rotated inward, and the short rotators divided; then the posterior flap is cut by carrying the knife behind the head of the bone and bringing it downward and outward. All vessels are to be caught and tied.

Esmarch's Method.—This operation has two steps, a circular thigh amputation 6 inches below the trochanter, followed by the removal of the remaining portion of the femur through an external lateral incision.

Senn's Method.—This is a complicated procedure by which the head of the bone is enucleated and brought out through an external incision. A rubber tourniquet is passed into the wound, and brought out through a small opening on the inner surface. The tourniquet is cut, and one part tied about the thigh in front, the other carried behind, crossed, and tied in front higher than the first. Flaps are then fashioned, and the limb removed by a circular cut.

The Circular Method (Fig. 114, *bb*).—No special description of this is needed. A circular skin-incision is made 6 inches below the anterior superior spine of the ilium. The muscles are divided down to the bone in the same manner at a higher level. The joint is then opened.

Wyeth's Bloodless Method.—This operation is without doubt the simplest, safest, and best method we have for hip-joint amputation. It can be done quickly, and there is practically no blood lost. The technic may be briefly outlined from the description given by Wyeth,[1] as follows: The patient is placed with the sacrum upon the corner of the operating-table. The limb to be amputated should be emptied of blood by applying the elastic bandage, except where contra-indicated, as before noted. Two steel needles are required, $\frac{3}{16}$ inch thick and 10 inches long. Their introduction is described by Wyeth in the following manner: "One pin enters $\frac{1}{4}$ inch below the anterior superior spine of the ilium and slightly to the inside of this prominence, and is made to traverse superficially for about 3 inches the muscles and fasciæ on the other side of the hip, emerging on a level with the point of entrance. The point of the second needle is thrust through the skin and tendon of origin of the adductor longus muscle $\frac{1}{2}$ inch below the crotch, the point emerging an inch below the tuber ischii." The points of the pins are shielded by corks, and the tourniquet wound five or six times very tightly about the limb above the pins. The Esmarch bandage is now removed. A circular incision is made in the skin about 6 inches below the tourniquet, and a longitudinal cut from the tourniquet, in the line of the trochanter, to join it. The integuments are dissected back, and the soft parts divided down to the bone by a circular sweep even with the lesser trochanter. The larger vessels are now tied. All muscular insertions should now be separated from the trochanters and upper part of the femur. This brings the operator down to the capsular ligament, which is cut through, and the limb disarticulated by manipulation after division of the ligamentum teres. Nothing now remains to be done but to tie the other vessels and close the wound by sutures. The vessels to be tied at this stage are the sciatic and obturator and the descending branches of the external and internal circumflex arteries. Wyeth recommends suturing the stumps of the divided muscles with catgut, in order to stop the oozing by quilting large surfaces of muscle together.

[1] A complete account of the operation may be found in Wyeth's article in the *Annals of Surgery*, 1897, vol. 25, p. 129.

EXCISION OF BONES AND JOINTS.

The term "excision of a joint" means the removal of one or all the extremities of the bones which enter into the formation of any given joint. When only one extremity is excised, the excision is "partial;" when all the extremities are excised, the excision is "complete."

"Resection" means the removal of the entire thickness of a bone.

Joints are excised for the relief of various conditions, such as disease, especially when well advanced, trauma, old unreduced dislocations, ankylosis in faulty position; also for the purpose of obtaining motion. Excision may save the patient from an amputation.

Certain general principles should govern all excisions. All diseased tissue should be carefully removed, whether it be bone or soft parts, although the utility of most joints will depend upon the preservation of tendons, and usually upon as little sacrifice of bone-tissue as possible. In children, extensive resection will prevent the normal growth of the limb. In all cases a good position of the limb will depend upon the care with which the excision is conducted, but in the knee-joint extraordinary care is necessary in order to obtain a straight leg.

Excisions call for strict asepsis, much skill in the application of splints, and good judgment in managing the convalescence. All tourniquets should be avoided if possible.

The results following excision depend upon the cause for which the operation is undertaken, the age and general condition of the patient, as well as the mode of operation and care received during convalescence.

It is not to be expected that the function of a joint will be completely restored, but the nearest approach has been obtained by the so-called "subperiosteal method," to be described later. In general, however, the results derived from excision are good, and the mortality is not high.

Excision of the Shoulder-joint.—*Von Langenbeck's Method.*—The shoulder-joint is a lax joint formed by the articulation of the head of the humerus with the glenoid fossa of the scapula. A loose capsule, re-enforced by several muscles, keeps these bones more or less in approximation. Excision of the shoulder-joint is usually "partial," because commonly only the head of the humerus is removed. The coracoid and acromion processes and the greater and lesser tuberosities are important landmarks. The contour of the deltoid muscle, the direction of its fibers, and the posterior position of the circumflex artery and nerve are important considerations.

There are various methods of approaching and excising this joint. All flap operations which sever the deltoid fibers are no longer in general use, and the joint is best approached by means of an incision roughly parallel with these fibers. Having reached the capsule, the head of the humerus may be exposed and excised by means of the open or the subperiosteal method.

The patient is placed on his back with the shoulders somewhat elevated and near the edge of the operating-table, and the flexed arm is controlled by an assistant. The capsule may be exposed by one or two incisions.

Von Langenbeck's incision (Fig. 115, *B*) starts at a point just external to the acromioclavicular articulation, and is carried directly downward for about 4 inches, passing through the thickness of the deltoid so as to expose the capsule and the greater tuberosity, the arm having been rotated somewhat inward.

Ollier's incision (Fig. 115, *A*) is anterior to this one, and commences at a point near the tip of the coracoid process, follows the direction of the fibers of the deltoid downward and backward for about 4 inches,

FIG. 115.—Excision of the shoulder-joint: *A*, Ollier's method; *B*, von Langenbeck's incision; *C*, Hueter's incision.

and is also carried boldly down to the capsule and greater tuberosity of the humerus. The latter incision is preferable.

Exposing the Head of the Humerus.—The long head of the biceps is sought for, and should always be preserved. The capsule is opened by an incision external and parallel to this tendon, made from below upward. The operator must now decide for himself as to whether he will use the open or the subperiosteal method. The former is the more common and easier procedure; the latter is more difficult and less frequently practicable, but gives the best results. In performing the open method, the edges of the wound are retracted, the biceps tendon drawn inward, and as the assistant adducts and rotates the humerus the insertion of the capsule, together with the tendons of the supraspinatus, infraspinatus, and teres minor muscles, is severed. The biceps tendon is then retracted externally and rotated in the opposite direction, so as to expose the subscapularis tendon, which is to be severed together with this portion of the capsule. The head of the bone can now be forced up out of the capsule, the remaining portion of which can be cut across if necessary, and the head of the bone be

excised by means of the saw. This method severs the scapular muscles from the humerus. It is well not to remove any more of the bone than is necessary, particularly in children.

The object of the subperiosteal method is to preserve the attachment of the scapular muscles. The capsule is exposed and opened as above, and the biceps tendon retracted in a similar manner. By means of a periosteum-elevator, as the arm is rotated the periosteum, capsule, and tendons of the scapular muscles are separated from the bone in one continuous layer, so as to expose the head of the humerus and more or less of the tuberosities. The bone is then forced out of the joint and excised.

Transverse Incision (*Nélaton*).—In certain instances it will be necessary to remove a portion of the glenoid fossa and to supplement the original incision by a transverse one.

Excision of the Elbow-joint.—Excision of the elbow-joint should be "complete," for a "partial" excision is more liable to be followed by ankylosis—a result to be avoided at the elbow. Nevertheless, care must be exercised in order that too much bone be not excised, for this may leave a loose and consequently inefficient joint.

FIG. 116.—Excision of the elbow: *a a*, von Langenbeck's incision; *b b*, Ollier's incision.

The bony landmarks consist of the internal and external condyles and intervening articular surface, the coronoid and olecranon processes, and the head of the radius. The other structures to be observed are the internal and external lateral ligaments, the ulnar and posterior interosseous nerves, and the tendons of the triceps, biceps, and brachialis anticus muscles. These two latter tendons should never be severed. There is danger of severing the ulnar nerve. The variety of operation which preserves the integrity of the most ligaments, tendons, and periosteum is the most satisfactory. The operation should consequently be as subperiosteal as possible.

The **posterior longitudinal incision** is the one usually employed (von Langenbeck, Fig. 116, *a*). The arm is flexed and held with the humerus nearly vertical, and a posterior longitudinal incision about 4 inches long is made so that its center is at the top of the olecranon process. This incision is carried directly to the bone, so as to bisect the triceps tendon and the posterior ligament. The next step consists in exposing the lower extremity of the humerus by removing periosteum, ligaments, and tendons in as continuous a layer as possible. This is best done with the elevator, using the knife sparingly. The inner half of the triceps tendon is first retracted, and then the internal condyle exposed, care being exercised not to injure the ulnar nerve. Then the external condyle is similarly denuded, and the soft

parts retracted from the exposed bone. The extremity of the humerus is now grasped with lion forceps and sawed across transversely just above the condyles. The forearm is now raised vertically, so as to expose the ends of the radius and ulna, which are to be freed a little, and then sawed transversely so as to remove a thin button from the radius.

The wound may be closed or not, according to the judgment of the surgeon, and should be placed upon a splint at an angle somewhat greater than a right angle, with the extremities of the bones not in approximation. Ankylosis is more to be feared in children. The fingers and wrist should be free and allowed to move.

In **Ollier's method** the joint is approached laterally, one object being not to sacrifice the triceps tendon. A cutaneous incision is made vertically along the interval between the triceps and supinator longus muscles for about 2 inches above the joint-line (Fig. 116, *b*), crossing the condyle below toward the olecranon process, along which it continues for an inch or more. A short vertical incision is made over the internal condyle, through which the internal lateral ligament is severed. By means of these incisions the bones are carefully denuded and excised as above; but this method is less practicable than the former.

The object of all elbow-excisions is the production of a healthy, movable joint. They are commonly performed for advanced cases of bone- and joint-disease, in which case both the bone and the soft parts must often be extensively sacrificed.

Excision of an Ankylosed Elbow.—An elbow is frequently ankylosed in an awkward position, and although it does not present any active pathological process nor give rise to any subjective symptoms, nevertheless such an elbow is not very useful, on account of the limitation of motion. The results of excision in such cases are very satisfactory.

The joint may be exposed by either the posterior or the lateral incisions. On account of the absence of pathological processes, it is necessary to sacrifice bone-tissue only, and the operation can be made as near the subperiosteal type as is possible. The incisions are to be carried as near the bone as possible, severing the capsule. With the periosteum-elevator one condyle is to be exposed, and then the other, working carefully from within the joint, and removing periosteum, ligaments, and all muscle-tendons in one continuous layer. This is often a difficult task on account of the irregularity of the bones. The greatest care should always be exercised to prevent injury to the ulnar nerve. When sufficient bone has been exposed, it may be removed by means of the saw or bone-forceps, first treating the humerus, and then the radius and ulna.

The after-treatment, as usual, consists in applying a splint which fixes the forearm at an angle of about 135 degrees, preventing a backward dislocation and securing absolute approximation of the fragments. Passive movements of all parts should be resorted to early, and the arm can soon be flexed to a right angle.

Reduction of Old Unreduced Backward Dislocations of the Elbow by Operative Measures.—In this dislocation the inferior surface of the coronoid process of the ulna is carried behind and above the

trochlear surface of the humerus, and the apex of the process tends to enter the olecranon fossa. New fibrous bands hold the bones in this abnormal position, and in time a new socket may be formed. Operative measures should be directed toward severing these bands, overcoming all adhesions, reducing the bones to their original positions, and maintaining them by means of apparatus.

The first incision is made over the external supracondyloid ridge, extending down to the condyle, and thence downward and inward, between the radius and ulna, so as to avoid the extensor group of muscles, and should terminate on the ulna. Through this incision all new bone-formation should be chiselled away, fibrous bands severed, and the sigmoid fossa cleared of all tissue. A curved incision is to be made over the internal condyle, the ulnar nerve isolated, and all fibrous bands divided. The parts are to be manipulated until perfectly free, the bones to be replaced, the wound closed, and the parts to be immobilized with an internal angular splint.

The arm must be watched carefully, in order to avoid a recurrence of the dislocation, and in the course of three or four weeks passive motion should be commenced.

Excision of the Wrist.—This operation consists in the removal of the carpal bones, as a rule; but in order to be complete the lower extremities of the radius and ulna and the proximal extremities of the metacarpal bones should also be excised. The more usual indications are chronic disease of the bones or their joints.

In order to perform this excision with dexterity the anatomical features of the bones just mentioned must be understood. The carpal bones are united by a capsular ligament strengthened in various places, so that with care it may be removed as a single layer both anteriorly and posteriorly. Posteriorly and laterally the bones at the wrist are practically subcutaneous; but anteriorly there are many tendons, nerves, and vessels. The posterior tendons serving as guides are the extensor longus pollicis and the extensor tendons of the index finger, the radial artery lying to the outer side of the former tendon; while between the tendons (Fig. 117) is a space crossed by the radial nerve, and offering a safe means of approach to the radial end of the carpus. In this space are the two extensor carpi radialis tendons. On the radial side are the extensor tendons of the thumb and its metacarpus; on the ulnar side are the extensor and flexor carpi ulnaris tendons. The exterior tendons crossing the carpus posteriorly need not be disturbed. Anteriorly are the deep and superficial flexors of the fingers and long flexor of the thumb, together with the median and ulnar nerves and radial and ulnar arteries. The trapezium is important surgically from the fact that it supports the thumb with its muscles, is in close proximity to the radial artery, and that a groove on its anterior surface lodges the long flexor tendon of the thumb. Hence this bone should be preserved, if possible. The upper bones of the carpus correspond roughly to a line, convex upward, which connects the two styloid processes. The arteries most liable to be wounded are the radial, the carpal arches, and the deep arch.

Bilateral Incision.—This operation is likely to be long and tedious, but should be made as subperiosteal as possible, with only the necessary sacrifice of tendons. The radial incision is made first. It should

commence on a level with the radial styloid, over the center of the posterior surface of the radius, and be carried downward to the inner side of the first carpometacarpal articulations (Fig. 118, *a*), thence along the radial side of the second metacarpal for half its distance, making an incision about 4 inches long. It lies to the ulnar side of the extensor longus pollicis muscle, should be carried to the bone, and it will probably sever the two extensor carpi radialis tendons. The ulnar incision is on the inner side of the wrist, commencing about 2 inches

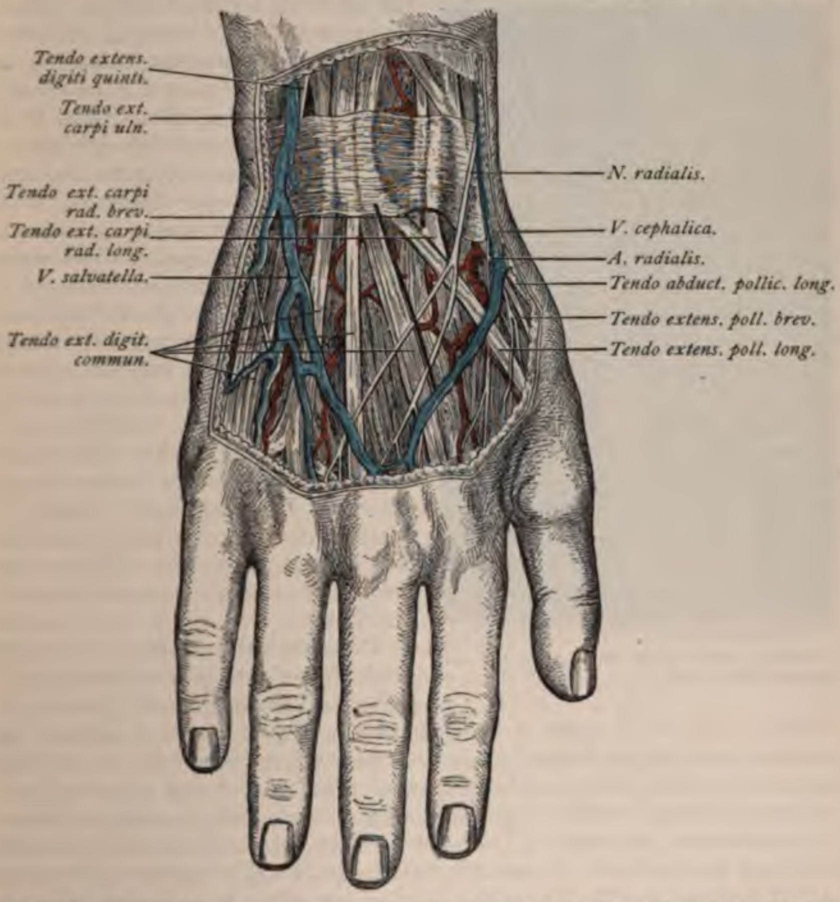

FIG. 117.—Topography of the dorsal surface of the hand: Langenbeck's resection-incision.

above the ulnar styloid process, and is carried down between the two ulnar carpal tendons and reaches as low as the middle of the fifth metacarpal bone (Fig. 118, *b*).

The next step consists in removing the carpus as subperiosteally as possible; it may include the carpus as a whole, or each bone may be removed as it is freed. The trapezium is separated from the carpus and preserved, if possible, as is the pisiform also. By means of an elevator the periosteum and tendons are separated from the carpal bones ante-

riorly and posteriorly, aided by alternately flexing and extending the hand and working through both incisions. On the radial side we must guard against injury to the radial artery and the long flexor tendon of the thumb, if the trapezium must be removed. On the ulnar side there is less to be injured. Thus all the carpal bones are to be bared and removed with as little injury to tendons as is possible. Thus far the tendons on the posterior aspect of the radius and ulna should not have been disturbed; but if it is necessary to resect a portion of these bones, the general layer of carpal periosteum is to be elevated, including the extensor tendons, exposing as much bone as may be necessary. The hand may be everted and these extremities removed through the ulnar incision, according to the exigencies of the case. The ends of the metacarpal bones are to be exposed and excised if necessary. The above incision is to be used for drainage if such is demanded. The forearm and hand are fixed by means of an anterior splint, and the fingers left free for passive motion. Care must be taken to keep the hand in good position until the tendons and bones become readjusted to their new position, and consequently the splint must be worn for a period of from two to six months. The results from this operation are not very satisfactory.

FIG. 118.—Excision of the wrist: *a*, radial incision; *b b*, ulnar incision; *d d*, von Langenbeck's incision.

Dorsoradial Incision (*von Langenbeck*).—A carpal excision may be performed through a single straight incision on the dorsum. It is carried along the ulnar side of the second metacarpal bone up on to the radius (Fig. 118, *d*), and is about 4 inches long. The edges of the wound are elevated and retracted laterally, the hand strongly flexed, and the carpal bones removed one by one. This incision is less convenient than the bilateral method, and is attended with the sacrifice of more tendons, as well as adding to the difficulties of an already complicated operation. The length of time necessary to perform the carpal excisions renders the use of the tourniquet objectionable on account of the subsequent tendency to hemorrhage.

Excision of the Hip-joint.—This is usually a "partial" excision, for only the upper extremity of the femur is removed. Anatomically we have to deal with a comparatively simple joint which is deeply surrounded by large muscles. The numerous methods of excision differ mainly in the situation of the primary incision. The most favorable location, however, is the outer and posterior aspect.

Von Langenbeck's Method (Fig. 119, *a*).—The thigh is held

flexed at an angle of 45 degrees and rotated inward. An incision about $4\frac{1}{2}$ inches long is made over the great trochanter, parallel with the shaft of the femur, two-thirds of which will be above the trochanter, and consequently over the joint. The gluteal muscles will be divided more or less in the direction of their fibers, and thus the incision is carried down to the bone and capsule. The latter is opened in the line of the original incision as well as by a second transverse incision close to the acetabulum. The muscles are severed from their trochanteric attachment, the ligamentum teres divided, and the head of the bone turned out into the wound. Denudation will be extended as may be necessary, and the exposed bone excised. The acetabulum should be curetted. It is safer to drain the wound.

FIG. 119.—Excision of the hip: *a a*, von Langenbeck's method; *b b*, Ollier's method.

Ollier's Method (Fig. 119, *b*).—This method sacrifices none of the gluteal muscles and preserves as much of the capsule as is possible. The incision is a curved one, beginning about 3 inches below the crest of the ilium, midway between the anterior and posterior spines of the ilium. It is carried downward and backward to the great trochanter, severing only the skin and fascia, thence along the shaft of the femur, through all the muscles, down to the bone. Its length will be about 5 inches. The lips of the wound are retracted, and the gluteus maximus will be seen to be posterior to the incision, and the fibers of the gluteus medius are in the line of the incision. These are to be separated, and not divided; likewise the fibers of the gluteus minimus. The smaller muscles about the trochanter and neck of the femur, such as the pyriformis, gemelli, and obturators, may be severed or retracted and the capsule exposed. The next step consists in opening the upper surface of the capsule from the acetabulum to the great trochanter; then, by means of the elevator, the capsule, periosteum, and tendons are removed from the upper extremity of the femur. The head of the bone is to be dislocated into the wound, the ligamentum teres severed if it is not already destroyed, and the head firmly grasped by forceps and then excised as extensively as may be necessary. The acetabulum is to be curetted as occasion demands. The wound is treated according to general principles. The after-treatment consists in fixation and moderate extension of the leg.

Anterior Incision.—The hip-joint may be approached by an anterior incision about 4 inches long, extending from below the anterior superior spine of the ilium toward the knee, roughly parallel with the inner border of the sartorius. No muscles need be severed. The joint is placed nearer the surface, but the acetabulum is not so well exposed.

This route has some advantages, but the lateral incision is the favorite.

Excision of the Knee-joint.—The success of this operation depends upon obtaining ankylosis in the extended position, and the excision should be "complete." Anatomically the knee is the largest articulation depending upon ligaments for its strength.

The semilunar incision is the one most used (Fig. 120). The knee is held partially flexed, and the knife is entered at the posterior and upper part of one condyle, and then carried down across the front of the joint, about $\frac{3}{4}$ inch below the patella, then up to a corresponding point on the opposite condyle. This incision includes only the skin. The knee is then to be flexed a little more, the ligamentum patellæ is divided, and then the lateral ligaments, and finally the capsule is severed, thus opening the joint. The knee is flexed still more, and by rotating the leg the crucial ligaments may be severed; but the strong posterior ligament is to be preserved. Elevate the flap, completely flex the leg, and free the condyles according to the conditions. As a rule, remove as little bone as is necessary, particularly in children. Remove the articular surface of the condyles by sawing from before backward in the horizontal plane of the articulation, and not at right angles to the femoral shaft, otherwise the deformity of knock-knee or bow-legs may be produced.

FIG. 120.—Excision of the knee with long anterior flap incision.

The semilunar cartilages should be removed and the extremity of the tibia made to protrude from the wound; then, by sawing from before backward, a thin lamina of bone is removed in the plane of the joint, injury of the soft parts being guarded against by retractors, and of the popliteal vessels by breaking off the last portion of this lamella. The patella should then be removed according to the judgment of the operator. All portions of the capsule, as well as all diseased spots, should be thoroughly removed. The ends of the bones should meet in perfect approximation, and may be wired or not, and the wound closed with or without drainage, according to the nature of the case.

The after-treatment calls for absolute rest and perfect fixation of the limb. If the wound does not suppurate, a good result may be expected; otherwise the case will be very tedious, and often a source of much pain. The results following this excision are not very favorable, so that cases of faulty ankylosis are best corrected by osteotomy.

Other methods of excision differ principally as to the line of incision.

Excision of the Ankle-joint.—Excision of the ankle-joint was formerly practised quite extensively, but nevertheless the results were not gratifying. Severe compound fractures about the ankle-joint were commonly treated by either excision or amputation, but the present surgical methods have rendered excision almost obsolete for this class

of cases. Gunshot wounds no longer call for excision as a routine. Tuberculosis at the ankle-joint is commonly overcome by other measures; or if the joint is seriously disorganized, amputation gives a more serviceable leg. Operation is furthermore discouraging on account of the large number of excisions which are followed by amputation. Cases of faulty ankylosis are best tested by osteotomy rather than excision. The after-treatment is tedious and uncertain, and frequently demands considerable mechanical skill in the application of splints so as to obtain fixation and at the same time permit surgical dressings to be applied where the wound has suppurated.

The ankle-joint is a hinge-joint, well supported by bone and held by strong ligaments. The operator must be familiar with the anatomy of the lower extremity of the tibia and fibula, the astragalus, and the os calcis. The lateral ligaments are strong, but the anterior and posterior are weak. Many tendons surround this joint, all of which are important in strengthening it, and should not be cut during the operation. Behind the outer malleolus are the two peronei tendons, which follow along the outer subcutaneous surface of the os calcis; and internally, behind the inner malleolus, are in general the plantar flexor muscles of the foot and toes. Anterior to the joint are the dorsal flexors, but the tendo Achillis is at a safe distance posteriorly. The tibial nerves and vessels need not be injured.

Lauenstein's Operation (Fig. 121).—The advantage of this method is that the joint can be well exposed by a single incision. This incision

FIG. 121.—Excision of the ankle.

begins near the shaft of the fibula, about 2 inches above the malleolus, and is carried down just below the extremity of the bone, and then curves forward toward the dorsum of the foot, terminating in the vicinity of the astragaloscaphoid articulation. Over the fibula the incision should be carried to the bone, then with the elevator the periosteum is reflected backward, carrying with it the two peronei tendons undisturbed in their sheath. The periosteum is likewise reflected from in front of the fibula. The external lateral ligament is to be cut, and then the malleolus entirely exposed, and at this point the lower inch or more of this bone removed by saw or forceps.

Continuing with the elevator, the anterior and then the posterior sur-

faces of the lower extremity of the tibia are to be exposed, during which process the tendons and other structures are to be retracted respectively forward or backward. It will now be possible completely to invert the foot at this articulation, thereby exposing the joint-surfaces of the tibia, fibula, and astragalus (Fig. 122). These surfaces are to be treated according to the principles governing cases of resection, as considered above. It is advisable to remove as little tissue as is consistent with expediency. The foot is then to be replaced and the wound closed.

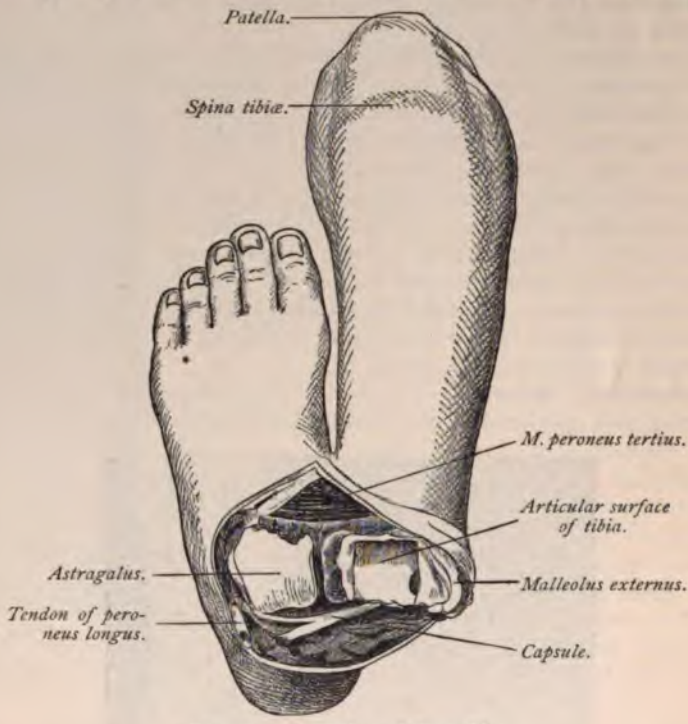

FIG. 122.—Resection of the ankle.

Bilateral Incision.—The outer incision is carried down over the fibula as above; but at the tip of the bone it is usually carried only a short distance either forward or backward. The internal incision is a short one over the lower portion of the internal surface of the tibia and internal malleolus. Through this incision the periosteum and ligaments are removed from this bone, and through the external incision the parts are treated as in the unilateral operation. When the diseased tissue has been removed, the wounds are to be closed.

After-treatment.—Favorable cases can be closed without drainage, and the leg fixed with plaster of Paris; but such results are not the rule. The cause of operation in most instances is such that suppuration is unavoidable, and this complication renders the after-treatment laborious and very uncertain as to its outcome. The problem is to maintain fixation and rest with the foot in good position, and yet allow access to the wound for dressings. Various contrivances may be used, such

as fenestrated plaster casts, posterior wire splints, or even a special apparatus for particular cases. The discouraging feature in most of these suppurative cases is that, after months or years of treatment, amputation must be resorted to in order to obtain a useful limb.

Arthrectomy or Erasion of a Joint.—The close relation between arthrectomy and excision is such that this method of treating diseased joints should be considered briefly in this connection. By the term arthrectomy or erasion of a joint we mean the thorough exposure of the joint by one method or another, together with the thorough removal of the diseased tissue alone. Hence this method cannot be applied to extensively diseased bones and joints, but only to cases where the destruction is still superficial. It is practically a curetting of the joint, and is to be used particularly in the early stages of articular disease. The operation must always be performed with care, and it requires experience to determine when all the pathological tissue has been removed, particularly in the cancellated bone. Arthrectomy offers the advantage of a little or no shortening of the limb, as well as but slight tendency to deformity. For the reason that it is a measure suitable for early cases, the results are more favorable than those following excision.

As a rule, each joint must be exposed by the methods used in excision of the same joint; but the loss of tissue and the mutilation necessary in the two operations are very different, hence the better immediate prognosis in cases of arthrectomy. In point of fact, most cases of excision are modified by the operation of erasion. For the reason that the exact condition of a diseased process in a joint can often be determined only after it has been opened and explored, it is well to begin the operation with the idea of performing an arthrectomy. Extreme cases of joint-disease will probably be more benefited from all points of view if an amputation is performed at the outset, thus avoiding a long period of suppuration with possible serious consequences.

OSTEOTOMY.

Osteotomy is the term used to describe any division of a bone *in situ;* but practically it means the division of bone for the relief of deformity. This limits the operation to the correction of deformity following fracture, of the distortion of rickets, and of certain ankyloses following joint-disease.

Osteotomy may be performed either with the saw or with the osteotome. The latter is to-day the instrument of choice for nearly all operations of this class. It can be handled with equal or greater precision, though it requires rather more skill than the saw. It involves less risk of injury to the soft parts, and does not fill the wound with bone-dust and chips, which may be innocuous, but may act as foreign bodies and become the starting-point of an infection.

The osteotome in common use is that of Macewen—substantially a simple chisel, but with an edge not bevelled, but ground evenly from both surfaces. The sides are straight; the cutting-edge is straight and of a width of $\frac{3}{8}$ to $\frac{3}{4}$ inch, usually about $\frac{1}{2}$ inch. It is well to have osteotomes of different thicknesses, so that the thinner may be used to

complete the cutting with less risk of becoming wedged or of splintering the bone. Markings on the blade at ¼-inch intervals make it easy to judge of the depth reached by the cut. The mallet used is preferably a moderately light carpenters' wooden mallet, rather than the steel or lead ones sometimes advocated.

For the performance of the operation, the limb, after careful antiseptic preparation, is placed firmly on a sand-bag, and an incision is made at the desired point.

There is rarely need of the free incision often advised; the small space needed for inserting the osteotome is gained by a short scalpel-cut reaching to the bone, though it is often practicable to drive the chisel itself through the skin and down to the bone. The bone once reached, the blade is turned to the desired position, avoiding damage to the periosteum, and the bone is cut with repeated hammer-strokes, the chisel being firmly held in the left hand, the outer side of which should rest on the skin, to avoid slipping. After each cut the chisel should be slightly lifted or rocked by the left hand to avoid wedging; it should never be removed from the bone, as the cut made may easily be lost. The osteotome is to be directed now forward, now backward, as needed to ensure cutting the full width of the bone, until about two-thirds or three-fourths of the thickness of the bone has been traversed, when an attempt is made to correct the deformity. The mechanism is, in children, a bending of the uncut portion with gaping or impaction, as the case may be, of the opposite side. In adults the bone more usually breaks across.

Cuneiform osteotomy is required only where there is much deformity. In such cases the wedge removed will correspond to the deformity; but it is always less in width than would theoretically be needed to ensure a full correction. Here again correction may be obtained without cutting through the entire bone. The operation requires, of course, a larger incision than linear osteotomy, in order to allow for cutting as well as the subsequent removal of the wedge. It is a severe as well as a somewhat more difficult operation. In certain cases, as in bony ankylosis of the knee in the flexed position, it is essential to remove bone; but unless the total thickness of bone is very considerable, a very accurate adjustment of the cut surfaces is not essential to the result.

Osteotomy for Faulty Ankylosis of the Hip-joint.—This operation is carried out in the treatment of certain cases of ankylosis in which the hip is fixed or its motion limited in such a way that the normal erect attitude is impossible. This includes not only the cases of actual ankylosis of the joints, but cases in which there is some little motion preserved at the hip, and in which the position of the limb is such as to preclude normal use. Most usually these operations are done to better the condition of imperfectly cured tubercular disease. The result aimed at is in no sense a restoration of joint-function, but a fresh ankylosis in improved position.

The osteotomy is performed either through the femoral neck or across the shaft below the trochanter.

I. **Through the Neck of the Femur** (*Adams's Operation*) (Fig. 123, *A*).—Adams writes: "The narrow-bladed knife is pushed in till it reaches the neck of the femur, at a right angle across the front of which it is then carried. The knife is then gently moved to cut a space for

the easy insertion of the saw, which, traversing the course of the knife, reaches the front of the neck of the femur, and gradually cuts it completely through. The surgeon cuts until he feels that the saw is free of the bone, and moving in the soft tissues only behind the bone." The point for beginning the incision is about a finger's breadth above the great trochanter. The saw used for this operation is the special one shown in Fig. 124.

FIG. 123.—Osteotomy for ankylosis of hip: *A*, intracapsular (Adams's) operation; *B*, extracapsular (Gant's) operation.

The operation may be performed equally well with the osteotome; the incision is made in the same way, the osteotome introduced and turned to a right angle with the femoral neck, which is then simply divided across.

The operation has certain drawbacks: first, it is inapplicable in the frequent cases in which the femoral neck is shortened or absorbed as a result of disease; secondly, satisfactory reposition is not always easy after the bone is completely divided.

II. **Through the Shaft of the Femur below the Trochanter** (*Gant's Operation*) (Fig. 123, *B*).—The incision for this operation is $1\frac{1}{2}$ inches below the trochanter major; it may well be made with the chisel, which is driven through the skin directly inward till it reaches the bone,

FIG. 124.—Adams's saw for subcutaneous division of the neck of the femur.

and then turned till the blade is at right angles to the line of the femoral shaft. The bone is cut across just below the lesser trochanter. It is well not to divide the bone entirely, but to leave a small portion to be broken when the deformity is corrected, thus ensuring better apposition of the fragments. The limb is put up with proper correction of previous deformity; and if there is some shortening, this may be practically equalized by slight abduction of the leg in the fixation-apparatus. It may sometimes be necessary, in order to correct fully, to divide contracted bands of fascia through an incision anterior to the joint. Confinement to bed for about six weeks is necessary.

The results are excellent, and, though it is theoretically less nearly correct, this operation is preferable to that of Adams in a great majority of cases. The longer incision and the excision of a wedge, advocated by Volkmann, seem to be unnecessary in practice.

An operation is described (Volkmann) by which correction of the deformity is attained, and an attempt made to secure a serviceable false joint. The bone is cut across below the trochanters, and the upper end of the shaft shortened to give room, and rounded off to fit into a cup scooped out of the trochanter. Cases are reported sufficiently successful to show the possibility of such a result, but the method is as yet insufficiently tried to be regarded as established.

Osteotomy for Genu Valgum.—This operation is performed in all adult cases of knock-knee requiring treatment, and in children in most cases in which the deformity that follows active rickets has taken place. It has been done as early as the third year; but permanently good results may be more confidently expected if four years be taken as the limit. Various open operations for the rectification of knock-knee have been performed, to say nothing of the methods of forcible correction, osteoclasis, etc.; but the only operation accepted as a routine measure to-day is the supracondyloid osteotomy. The deformity in the usual form of knock-knee depends essentially upon a relative overgrowth of the inner condyle of the femur. This cannot be perfectly corrected; but by changing the direction of the bone just above the growing epiphysis, a straight general line is given to the leg, and the deformity resulting from the operation is trifling (Fig. 125).

Macewen's Supracondyloid Osteotomy of the Femur.—For this operation the flexed knee is laid on its outer side on a sand-bag, and a longitudinal incision is made at a point ½ to ¾ inch above the adductor tubercle, anterior to the insertion of the adductor magnus. Either a scalpel is used, or the osteotome is driven directly into the bone, and then turned into such position that it will divide the bone in a direction outward and sufficiently upward to avoid the epiphyseal cartilage (Fig. 125). Care must be taken to move the chisel sufficiently to prevent its becoming wedged, and to direct it forward and backward enough to ensure cutting the anterior and posterior walls of the bone completely through. When two-thirds or three-fourths of the bone has been divided, an attempt should be made to correct the deformity. If the division has been properly carried out, the outer cortical layer of the bone bends or breaks, and there is impaction on the inner side, giving a complete correction with fixation of the fragments. Neither drainage nor sutures are necessary. A plaster-of-Paris bandage is worn for about four weeks, and the child allowed to stand on the leg at about six weeks, or even less, after operation. The functional as well as the esthetic results are excellent; the mortality is trifling (less than ⅓ per cent.).

FIG. 125.—Section of femur in knock-knee, showing line of section in Macewen's operation.

Accidental wounding of the anastomotica magna and injury to the peroneal nerve should be mentioned as rare complications that have occurred in connection with this operation.

Osteotomy of the Shaft of the Femur from the Outer Side.—The thigh is adducted and inverted, and a short transverse incision, 2 inches above the external condyle, is carried through the iliotibial band to the bone. The chisel is then inserted and the shaft cut through transversely till the outer surface is nearly reached; the correction is

then carried out as before. In this operation there is gaping rather than impaction of the cut surfaces.

This operation, though unobjectionable, has largely been abandoned for that of MacEwen.

Osteotomy for Faulty Ankylosis of the Knee-joint.—In cases of ankylosis in which forcible straightening is contra-indicated or impossible, a linear osteotomy above the condyles may be done, differing from the typical MacEwen operation only in that the anterior wall is completely divided, and the posterior instead of the external wall left uncut, to be broken across by the manipulations for correction. It may often be wise not to attempt full correction immediately, but to secure a partial correction, and reach the final result by straightening the knee a little more at each dressing. An advantage of this operation is that it makes it possible to preserve and use such motion as may have been present before correction.

The operation is an excellent means of correcting faulty ankyloses up to about 45 degrees of flexion; more extensive flexion with ankylosis is usually better treated by a wedge-shaped excision of the joint; or linear osteotomy of the tibia just below the knee may be added to the osteotomy of the femur.

Osteotomy of the Tibia.—Three operations are done on the tibia—linear osteotomy just below the tuberosities, performed in knock-knee or in ankylosis of the knee; linear osteotomy of the shaft for the correction of bowlegs or deformed fractures; and cuneiform osteotomy for the same purpose.

Osteotomy of the Tibia below the Tuberosities.—A transverse incision is made just below the tuberosities of the tibia, carried from the spine backward across the inner side, and the bone divided transversely, the chisel being driven from within outward as the posterior portion of the bone is reached, and great care being taken to avoid injury of the structures at the outer side.

By another method, an anterior longitudinal incision is used, and bent retractors are introduced behind the bone, between it and the soft parts, thus protecting the popliteal space from the final blows of the chisel.

The fibula is not always divided in this operation, but the danger of injuring the peroneal nerve is said to be lessened when this bone is carefully chiselled across. For this purpose an incision, a little below the fibular head, is carried direct to the bone, which is divided with the osteotome.

According to Kocher, the liability to damage of this nerve during the reduction is less if a *wedge-shaped* osteotomy of the tibia is resorted to, as less force need be used.

Linear Osteotomy of the Tibia.—This is the operation of choice for such bowlegs as cannot be dealt with by osteoclasis—especially for the "anterior bowlegs," in which the bend is usually a sharp and well-localized one, and for bends very near the epiphyses.

A rather broad osteotome is introduced through a knife-cut at the point of maximum curve; the bone is partly divided transversely, and the correction completed by the fracture. When there is marked deformity, the posterior wall of the tibia may be chiselled first; then

there will be a gap posteriorly instead of an anterior impaction. In this way something may be saved in the matter of shortening. Frequently a tenotomy of the tendo Achillis is necessary to a full and easy correction. Chiselling of the fibula is rarely required; the bone gives way in a green-stick fracture as the tibia is corrected.

The operation for deformity after fracture, not infrequently performed in this situation, is essentially the same, save that the fibula in these cases should usually be divided through an appropriate external incision.

Trendelenburg's supramalleolar osteotomy for the relief of flat-foot is practically the same operation.

Cuneiform Osteotomy of the Tibia.—This operation is rarely required, and is performed only in cases in which the deformity is extreme, and consists of a single bend in the bone. An incision is made over the convexity of the bend, and a wedge, corresponding to the degree and direction of the deviation to be corrected, is chiselled out and removed. The base of the wedge is usually directed anteriorly.

Osteotomy for Hallux Valgus.—This operation, according to Barker and Reverdin, is an improvement on the resection of the joints which was previously practised in these cases. An incision is made to the inner side of the great-toe joint, long enough to admit the osteotome about $\frac{1}{2}$ inch behind the joint-line. The bone is cut nearly through, then fractured into the desired position and held by suitable apparatus. In very severe cases it may be necessary to resect a wedge of bone at this joint to secure the desired connection. The result of either operation is good in all but the very worst cases.

In this class the operation described by Weir seems more complete, more rational, and more likely to give the best results. He advocates cutting the joint-capsule on the outer side, with partial resection of the head of the metatarsal, especially the hypertrophied inner and anterior surface. The cartilage of the phalanx is not cut, so that motion is preserved. The sesamoids are removed (their absence seems not to interfere with perfectly efficient flexion). In some cases preservation of the corrected position of the toe has been aided by transplanting the extensor proprius hallucis tendon to the inner side of the first phalanx.

Osteotomy for Inveterate Club-foot.—The removal of a wedge of bone with the apex at the inner side of the foot is not infrequently performed in cases of inveterate club-foot with marked deformity which have resisted all other means of treatment.

In this operation a wedge is removed irrespective of bony boundaries —a wedge composed externally mainly of the cuboid and the anterior end of the calcaneus, internally cutting through or including the scaphoid. It may, however, include parts of all the tarsal bones (Fig. 126). Various incisions are used. An oval may be excised externally, including the callus and the bursa present in these cases over the cuboid, with a corresponding simple vertical incision at the inner side. A T-shaped cut with the vertical arm running over toward the scaphoid may be used, or a simple transverse incision from the scaphoid across the dorsum of the foot to the outer side. In any case, the next step is

the pushing of the extensor tendons up and inward, the peroneous longus tendon down and back. The bones are carefully cleared with the periosteal elevator; then, the wound-edges being held separated with retractors, a wedge is removed with saw or chisel, so that the foot can be brought into a fully corrected position. This wedge should be so cut as to be brought out in one piece.

Suturing the bones in apposition is advocated, but is not really essential. Any hemorrhage is to be controlled, the external wound sutured with or without drainage, and the foot then fixed in plaster-of-Paris in fully corrected position.

FIG. 126.—Incisions for cuneiform resection of the bones in club-foot: *a b*, simple transverse incision; *a b c e*, T-shaped incision; *d*, oval incision.

Union should be firm in about six weeks; but the operation should be followed by massage and suitable exercises, and a retentive apparatus worn for a considerable time after this, if the best results are to be obtained. The results of this operation are good; but the operation is a severe one, and usually results can be obtained without so much sacrifice of bone, which necessarily results in considerable shortening of the foot.

A more rational form of osteotomy for club-foot consists in cutting a wedge from the anterior end of the os calcis, while a section of the neck of the astragalus, performed from the inner side, practically continues the line of the wedge incision, and makes full connection possible with substantially no loss of bone. If this operation be done, where needed, as the last stage of Phelps's operation—division of all resistant structures by open incision—it gives a means of correction in all cases save those with extreme deformity in adults, where the formal wedge-shaped osteotomy described above may still be necessary.

Operation for Talipes Equinus.—This operation, originated, as was that for equinovarus, by Davy, is substantially the operation just described, save that the base of the wedge removed is directed upward instead of outward.

For the skin-incision, either wedge-shaped pieces of skin may be cut out on either side corresponding to the bone-wedge to be removed, or T-shaped incisions may be used. Like the wedge-osteotomy for varus, this operation entirely disregards bony landmarks. It consists simply of stripping up and protecting the soft parts while such a bony wedge is sawed, or better chiselled out, as will enable the foot to be brought to the corrected position and held, with or without suturing the bones in place. The after-treatment is the same as that for the varus operation—fixation in a corrected position till bony union is completed; then massage and exercises till the foot is ready for use.

Operation for Flat-foot.—In cases of extreme flat-foot, a wedge-shaped osteotomy may be performed according to the method of Golding Bird. The wedge removed consists of the scaphoid, or of the scaphoid and part of the astragalus. For the best correction, the cut should extend across the full width of the tarsus to its outer border.

In this way adduction of the front part of the foot as a whole is possible, and moderately accurate apposition of the cut surfaces with restoration of the arch.

Cyston's operation is a wedge-osteotomy of parts of the scaphoid and of the astragalus. The astragalus and scaphoid are pegged in their relative positions after correction of the foot, the object aimed at being ankylosis of these bones.

Schwartz describes a wedge-resection which is substantially that of Golding Bird. The incision is made from ½ inch in front of the internal malleolus to the first cuneiform bone. The soft parts are stripped up, and a wedge-cut, irrespective of the joints, but including usually the scaphoid and a part of the astragalus, is removed. The foot is then fixed in corrected position, the internal cuneiform and the neck of the astragalus coming in contact.

In relation to these operations, it is to be remembered that they all necessarily sacrifice something of the "length" and of the elasticity of the foot, and can in no proper sense cure the deformity; while it is possible by mobilization, forced correction, mechanical support, and exercises actually to cure many cases and to give great relief to nearly all.

Golding Bird would limit operation to such cases as have persistent pain irrespective of support and correction, due, he thinks, to crowding together of the structures at the outer side of the foot. It is certain that the class of cases of flat-foot to be operated upon is confined to those in whom nothing is to be gained by other treatment, and in whom the relief of pain and the fair functional results attainable by the operation distinctly offset its disadvantages. This class of cases is decidedly a small one.

Operative Treatment of Ununited Fracture.—In the treatment of ununited fracture of the long bones—femur, tibia, and the bones of the upper and lower arm—many authors have recommended various measures to promote union without actual resection. These would seem of little or no value in well-established cases of non-union. There are, of course, the frequent cases of delayed union, not definitely separated as a class, in which union finally occurs apparently irrespective of treatment. In these cases no resection is needed; and now that we have the assistance of the *x*-rays, it will probably be possible to separate the cases in which resection is advisable, the established pseudarthroses in which no further repair is to be expected. These are of two classes—those in which a new joint has been formed, often a rough ball-and-socket joint; and those in which there has been not a new growth, but rather an actual absorption of the bone-ends.

Many methods of resection of bone-ends for these cases have been described, usually differing only in minor details of no very definite value. The simplest method, and probably the most efficient, consists of a transverse resection of the tips of the fragments, together with such external apparatus as is necessary to ensure close coaptation of the cut surface.

Operation by Resection of the Ends of the Bones.—This operation is usually simple, the points of most importance being the strictest antisepsis, free incision, and accurate coaptation. The incision is so placed as to reach the bone by the shortest route, and must be suf-

ficiently long to allow the free end of each fragment to be brought out of the wound. The bones should be well denuded of the tough cicatrix which surrounds them, and the denuded ends brought out within reach of the chisel or saw. This is important, not only in order to avoid injury of the soft parts, but to make the section of the bones more accurate. Either chisel or saw may be used, preferably the latter, and so much of the ends cut away as may be necessary to give a fresh surface of spongy bone. Great care should be used in making the section accurately transverse, as accurate coaptation of the fresh surface and easy retention of position depend largely on this point.

The after-treatment is carried out exactly on the lines of an ordinary compound fracture, except that extra care is to be taken in the matter of immobilization.

Operation by Wiring the Fragments.—In this operation the details of preparation—incision, the denuding of the bone-ends, and the removal of a portion of the ends—are carried out in precisely the same way as for simple resection. Then holes are drilled through the cortical layer, $\frac{1}{3}$ to $\frac{1}{2}$ inch from the cut edge, penetrating obliquely to the cut surface. The drill should be slightly larger than the wire to be used. Silver wire is chosen for this purpose. The piece of wire is inserted through the drill-holes, including in this way a portion of each fragment, the ends are brought together on the outside of the bone and twisted together with heavy forceps, cut short, and the twisted portion hammered down so as to lie close against the bone. Whether one or more points on the circumference of the cut bone are to be sutured, and where the sutures are to be placed, must be matters of judgment in each individual case.

The question of the advisability of using wire sutures at all is to-day a moot point. On the whole, the practice seems to have little actual evidence to support it. It is obvious that, even when freshly placed, sutures of this sort are a very imperfect mode of fixation; and when we consider that the presence of the wire determines absorption of the bone about it, with consequent loosening, it becomes clear that the wire, if useful at all, can act only to prevent lateral displacement. Whether this might not equally well be attained with other sutures is a question. It is true that there should be no danger from sepsis from the wire, and its presence is often entirely unnoticed by the patient for long periods of time. In other cases, on the other hand, the wire unquestionably acts as a foreign body, and causes irritation, late suppuration, and sloughing of the skin over it. These cases are particularly troublesome because of the difficulty of removing the wire, especially when it has been long embedded.

Apart from these considerations, the influence of the presence of the wire on the process of repair is more than doubtful. It is known that suppuration and necrosis may result, and that the wire causes some bone-rarefaction in its immediate vicinity. It seems only fair to assume that it must act to some extent as an irritant, and in many cases at least be prejudicial to union of the fragments.

From the standpoint of actual results, moreover, it may be said that simple resection, with proper and efficient immobilization of fragments, yields as good results as wiring.

Excision of the Upper Jaw (Figs. 127–129).—This operation, formally carried out, is practically limited to cases of new growths. Partial excision may be performed for a variety of causes, more especially for necrosis of the jaw.

Osteoplastic resections, so called, in which the portion temporarily displaced is not separated from the soft parts and is subsequently replaced, may be performed in cases of nasopharyngeal polypus, etc., when more room is needed than is afforded through the natural openings.

For the complete operation there are several methods of gaining access to the parts to be divided, all aiming at a minimum of displacement by the external incision, as well as at ease of access.

The bones to be divided in removing the whole of the upper jaw are: *a*, the nasal portion of the superior maxilla; *b*, the external portion of the maxilla, or, more usually, the malar bone itself just outside the junction; *c*, the orbital plate divided in combination with the cuts dividing *a* and *b* (Fig. 127); *d*, the median connection from the teeth to the soft palate. These points are divided in much the same way in all described methods.

FIG. 127.—Lines of section of bone in excision of the upper jaw: *abcd*, typical total resection; *fihgjk*, Ollier's operation; *abfg*, Guerin's operation; *cdlm*, removal of maxilla below orbital foramen.

The primary danger of the operation is from hemorrhage, and temporary ligation of the external carotid has been employed to lessen bleeding. It is not, however, usually done. The free hemorrhage involves much trouble in some cases from inspired blood, and some operators have preferred to do tracheotomy and use Trendelenburg's tampon-cannula, or, still better, insert a tracheotomy tube and plug the throat from above. Rose's position has also been employed. None of these measures is absolutely necessary, and it must depend on the case whether they are of sufficient value to make up for their disadvantages, or whether the operator will depend on ready and accurate sponging.

By Median Incision.—The typical incision for the operation is the median (Fig. 128, *a*). This starts from a point a little below the inner canthus, runs down alongside the nose, crosses to the middle of the lip, and is thence carried down in the median line, the lip being split through. The coronary arteries may then be secured, and the second incision carried from the upper end of the first incision outward along the lower edge of the orbit. The soft parts are then stripped back from the bone and the vessels secured. The nasal cartilages are freed from the bone, and the nasal process cut through with chisel or cutting-forceps. The orbital plate is then divided subperiosteally on the same line, the division being carried back to the sphenomaxillary fissure. The next cut divides the malar bone, and in line with it the orbital floor is again divided. The knife will suffice for this division. The

soft palate is separated from the hard with the knife or the thermo-cautery, the mucous membrane and periosteum of the palate are cut to the bone, an incisor tooth is drawn, and the whole bony median connection is severed with the chisel or saw close to the nasal septum. The flap, consisting of the soft parts of the face, is then dragged back till the soft parts can be cut back of the jaw as far as the pterygoid plate. The jaw can now be seized and wrenched down and outward, tearing it loose from its pterygoid attachment. The bleeding is checked as far as possible, the cavity packed, and the incision closed by sutures.

Subperiosteal Excision of Ollier.—The incision is made from a point on the lip just away from the corner of the mouth and carried up to the middle of the malar bone; or the operation may be performed through the usual median incision. The mucous membrane of

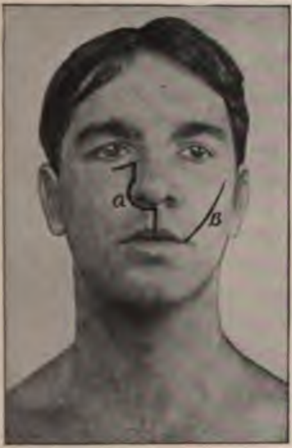

FIG. 128.—*a*, Median incision for excision of the upper jaw; *b*, external incision for the same operation.

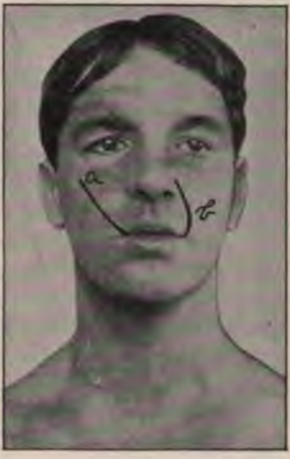

FIG. 129.—*a*, Incision for Ollier's subperiosteal excision of the upper jaw; *b*, incision for Guerin's operation.

the mouth is then cut from a point opposite the lateral incision, and carried close to the gum around back of the last tooth; then forward again, close to the gum on the inner side, opposite the point of beginning. From the beginning of this incision the periosteum is cut obliquely to a point just opposite the nostril. Beginning with this cut, the periosteum is stripped up till it has been raised from the whole front surface of the bone and from the whole orbital floor. The periosteum of the roof of the mouth is then freed, beginning with the incision described, and working to the median line.

The nasal and malar processes are then cut through, as in the usual procedure; but instead of cutting in the median line, this operation leaves *in situ* a wedge of bone bearing the incisor teeth, the bone-cuts running from the socket of the extracted canine tooth obliquely upward to the nostril and obliquely backward to the median line, thence directly backward to the soft palate.

After removal of the bone, the periosteal flaps from the roof of the

mouth and from the front of the bone are sutured together and the external wound sutured.

Excision of the Upper Portion of the Superior Maxilla.—This operation aims at leaving the whole alveolar process *in situ*, while removing the diseased upper portion of the jaw. The same incision is used as for total resection, and the soft parts are dissected up and reflected in the same way. The periosteum of the orbital floor is stripped up in its whole extent, and the nasal and malar processes divided and the orbital plate cut in the typical way. The isolation of the piece to be removed is then accomplished by a horizontal saw-cut from the nostril outward, passing above the teeth. This portion of the jaw is then pried or wrenched out of its bed and removed, leaving the alveolar process intact.

Excision of the Lower Portion of the Superior Maxilla (*Guerin*).—The incision for this operation runs from the ala of the nose to the corners of the mouth, following the nasolabial fold. The flap so outlined is dissected up, the mucous membrane being incised along the saw; the alveolar process is laid bare, and an opening made into the nostril from in front. A fine saw is then introduced into the nasal cavity, and the bone divided horizontally outward above the roots of the teeth, from the nostril to the lower edge of the malar bone, or through the malar process. The soft palate is next detached from the hard by a transverse incision, one of the incisor teeth extracted, and the median connection severed with chisel or saw. The portion included between these cuts is then wrenched down and out (Fig. 129).

Resection of the Posterior Part of the Hard Palate for Removal of Nasopharyngeal Polyps.—This operation gives a limited access to the nasopharynx by temporarily clearing away the roof of the mouth. For its performance the mouth is widely opened with a gag, and an incision made which splits the soft palate centrally for its full depth (see Fig. 130), and extends forward for about half the depth of the hard palate. From the anterior end of the incision transverse cuts are carried outward, outlining a flap on either side, which is then dissected up subperiosteally. The square of hard palate thus denuded is then chiselled out or removed with the saw or forceps. After the polyp is removed the soft parts are replaced, and the median incision closed as for a staphylorrhaphy.

Osteoplastic Resection of the Anterior Portion of the Palate for the Removal of Nasopharyngeal Polyps.—The attachment of the upper lip to the bone from one bicuspid tooth to the other is divided, thus allowing the nasal cavities to be open from the front. The canine teeth are then removed, and an incision is made, extending from each canine fossa to the posterior border of the palate, through the mucous membrane and periosteum of the hard palate. The alveolus and hard palate are then divided by a chisel along these lines. The nasal mucous membrane is divided, and this mass is turned back on the velum as on a hinge, admission thus being gained to the upper pharynx. After the removal of the tumor the resected portion is sutured in place (Fig. 130).

Resection of the Upper Portion to Facilitate Removal of Nasopharyngeal Polyps, leaving the Hard Palate and Alveolar Process

(*von Langenbeck*).—In von Langenbeck's operation two incisions are made, making two sides of a triangle on the face, with the base toward the nose. One incision starts from the ala of the nose, and, curving slightly downward, ends on the zygoma; the other, starting from the side of the nose, follows the floor of the orbit and nose to the first incision at about the middle of the malar bone.

The soft parts and periosteum are disturbed as little as possible, except along the floor of the orbit, where the periosteum is lifted from the bone as far back as the sphenomaxillary fissure. The origin of the masseter is then cut where it appears in the incision. A director is now passed to the outer wall of the nasal cavity, passing under the zygoma and through the pterygomaxillary fissure. A finger in the mouth can detect the end of the director. The director is withdrawn, and a fine saw, edge up, is passed along this line. The malar portion of the zygoma is cut across. Passing through the sphenomaxillary fissure, the floor of the orbit is divided, the incision ending just short of the lacrimal bone. The saw is then removed and introduced through the pterygomaxillary fissure, edge downward. The walls of the antrum are divided, following quite closely the cutaneous incision, and the lower part of the anterior nares is entered. An elevator is now introduced into the pterygomaxillary fissure, and the separated portion of the maxilla, with the covering of skin and periosteum, is pried toward the middle line, upward and inward. This fragment receives the blood-supply through the soft parts at the base of the triangle on the side of the nose. As the bones of the nose are not much disturbed by the operation, at its close the resected portion can usually be held in position by cutaneous sutures and pressure. No drainage-tube is required. The disadvantages of the operation are its difficulty, resulting paralysis from division of the branches of the facial nerve, and occasionally injury to the lacrimal duct.

FIG. 130.—*a a a a*, Incision in resection of back part of the hard palate; *b b*, incision in Ollier's subperiosteal jaw-resection.

Excision of the Inferior Maxilla.—The whole or any portion of the lower jaw may be removed. The incision will depend on the extent and situation of the part to be excised. It may lie entirely within the mouth, or externally along the lower border, and, if necessary, along the ramus of the jaw. The following anatomical relations are of importance: The internal maxillary artery runs forward beneath the ramus of the jaw and along the lower border of the external pterygoid muscle, and then obliquely upward and forward. The lingual nerve runs between the internal pterygoid muscle and the ramus of the jaw. Stenson's duct runs about a finger's breadth below the

zygoma, with the facial nerve. The facial artery crosses the lower border of the jaw, at the anterior margin of the masseter muscle. Division of the attachments of the geniohyoglossus muscles to the bone deprives the tongue of its support and permits it to fall back upon the glottis. Therefore it may be necessary to pass a suture through the tongue. At the close of any form of resection the buccal mucous membrane and deeper tissues should be sutured, and any drainage that is necessary done from outside.

Resection of the Anterior Portion of the Body.—This may be accomplished by any one of the following incisions: A vertical one in the median line of the lip, a curving incision under the lower border of the chin, or an incision inside the mouth. Whatever the incision, the bone is cleared of muscular attachments, two teeth drawn at the limits of the portion which it is proposed to excise, the bone sawed through, and the ends drawn together and fastened.

Resection of the Lateral Portion of the Body.—The incision starts from the angle of the jaw, and, following the facial border, extends to the symphysis, where it turns upward to the base of the lower lip. The lip need not be divided entirely. The periosteum may or may not be lifted, as is desired. The bone is cleared not quite to the median line, so as not to disturb the attachments of the geniohyoglossus muscle, and sawed through at this point, after a tooth has been drawn, if it is necessary. The soft parts are scraped away from the bone as they are brought into view, and pulled downward and outward. A tooth is drawn, marking the posterior limit of the part to be removed, and the bone is sawed through. The mucous membrane should be accurately adjusted, that healing may occur as soon as possible. As soon after the operation as possible an apparatus should be worn to hold the remaining half of the lower jaw in proper relation to the upper.

FIG. 131.—Incision for resection of the lower jaw.

Resection of the Ramus and Half of the Body (Fig. 131, *b*).—The incision, beginning just in front of the ear, below the inferior edge of the zygoma, is continued to the angle of the jaw, and along the inferior border of the ramus to ¼ inch below the symphysis, where it meets a vertical incision coming down from the middle of the lower lip. The flap thus marked out is dissected back, and the facial artery tied. According to the nature of the case, the periosteum may be removed with the bone, or the resection may be subperiosteal. If the periosteum is to be removed with the bone, the operation is continued by drawing a tooth and dividing the bone by a saw. Then, pulling the jaw forward and downward, the inner surface of the bone is cleaned of soft parts, separating the mucous membrane and the pterygoid muscle. The inferior dental nerve is divided, and the insertion of the temporal muscle to the coronoid process is cut

across. Then, after separating the soft parts from the external surface of the bone, including the external pterygoid, the condyle is twisted out of the joint and the bone is free.

Resection for Ankylosis of the Jaw.—Ankylosis of the jaw may be due to contraction following severe and destructive forms of inflammation where the trouble is not limited to the articular surface, of which cancrum oris may serve as a type, or to bony or fibrous union of the condyle and temporal bone. The first form of ankylosis is dealt with by removing a wedge-shaped piece of bone from the horizontal ramus, anterior to the adhesions, usually in front of the masseter, to form a false joint at this point. When there is bony union of the joint-surfaces excision of the condyle is indicated. The incision is made over the joint, just anterior to the temporal artery, beginning at the lower border of the zygoma. The space is enlarged by a horizontal cut from the upper end, following the lower edge of the zygoma. This flap is reflected forward, with care not to injure the facial nerve. The muscular fibers arising from the zygoma passing over the joint are separated and the capsule is opened. The neck of the condyle is freed and divided with a chisel, and then, grasped by forceps, is twisted and cut free from the bone. During the operation all instruments should be kept close to the bone, to avoid injuring important structures. Some temporary facial paralysis may follow the operation. It is important that passive motion should be begun in a few days after either operation, and should be regularly practised. Screw-gags and graduated pieces of cork may be of use in helping the patient to open his mouth. If the motions cause much pain, it would be well to administer gas or some anesthetic to the patient for the first few times. Unless the after-treatment is conscientiously carried out, relapses are likely to occur.

Resection of the Sternum.—Fragments of the sternum have been frequently removed for shot injuries, with very slight mortality. If the periosteum can be left, new bone quickly forms. The incision is vertical or crucial, depending on the amount of bone to be removed. At times it may be advantageous to use a trephine before taking a gouge or chisel. The structures lying close to the posterior surface of the sternum must be carefully avoided. The costal cartilages may be divided with a strong scalpel, and the sternum itself with a saw.

Resection of the Ribs.—The incision follows the curve of the middle of the rib to be resected. Its extent corresponds to the amount of rib to be removed. The incision is carried down to the bone, and the periosteum is separated from the rib from behind, as well as from the front, by a blunt dissector; or, if this is impossible, the rib is scraped free from soft parts. The intercostal artery, which lies in the groove in the inferior border of the rib, must be avoided, and the desired amount of bone cut away with bone-forceps, care being taken not to injure the costal pleura. If portions of several ribs are to be excised, the original incision can be enlarged by vertical cuts at either end.

For long-standing cases of empyema in which there is a large cavity between a retracted lung and a rigid chest-wall, Estländer devised a *thoracoplastic method* of filling up this cavity. To obliterate this space, the chest-wall is made to sink in by simply dividing some of the ribs or

by removing portions of them. Each case has to be considered somewhat by itself, and the incision is made in such a way as to allow the greatest amount of sinking in of the chest-wall. Ordinarily the incisions form two sides of a very acute triangle, the base being up, and are wide enough apart to permit removal of sufficient portions of the ribs; or a horizontal incision along a rib, with a vertical one rising from its middle, will open up the same area. The lower rib is usually first removed subperiosteally, and the side examined to determine the amount of the other ribs necessary to take out. The process is the same for each rib. Any bleeding from the intercostal arteries can easily be controlled. In Schede's operation portions of the thickened costal pleura are also removed to permit more complete sinking in of the chest-wall. These operations nowadays are scarcely justifiable, as the contraction of the side produces extremely severe forms of lateral curvature.

Excision and Resection of the Clavicle.—The clavicle lies so near to the important structures in the neck that operations on it have been attended with some risk. When the normal relation of the parts has been destroyed, as by morbid growths, the excision of this bone may prove a very serious operation. When the periosteum, however, has been loosened by an osteitis, it is quite simple. The *subperiosteal method* gives the best results. The scapular extremity is broad and flat, and is exposed by a curved incision with its convexity forward and a little outward. The bone is well exposed by turning back this flap. If the periosteum cannot be separated, the muscular attachments of the deltoid, pectoralis, trapezius, and sternomastoid are divided, the joint opened, and the end of the clavicle removed. The sternal extremity is removed by an incision over the sternal end, curving downward, the flap is raised, and a saw slipped under the bone where it is to be divided. After it has been cut, the muscular attachments are to be divided and the bone disarticulated. The incision for removal of the clavicle as a whole runs along the lower border of the bone, and, if necessary, may be enlarged by a vertical incision at its ends. The bone is freed all around as much as possible, and the acromial end raised; then, separating the periosteum on the anterior, inferior, and posterior surfaces, or the muscles, as the case may be, and dividing the ligaments, posterior, inferior, and superior, the clavicle is lifted up until the sternal end is disarticulated. The risk of wounding the vessels of the neck, the pleura, or the thoracic duct is reduced to a minimum by keeping close to the bone and always cutting against it, and by raising the acromial end, as in the method described, thus giving more space when the important structures are approached.

Excision and Resection of the Scapula.—Where removal of but a portion of the scapula is required, no definite rules can be laid down for the excision. The operator must be guided in making his cuts by the amount to be taken away. Usually the operation for the removal of the whole of the scapula follows the method devised by Ollier. The scapula is well exposed by placing the patient on his sound side, close to the edge of the table. An incision is made along the whole length of the spine of the scapula. Two other incisions begin from its posterior end, one following the posterior border to the inferior

angle, the other upward and forward for a short distance. The flaps are turned back, and the muscular attachments of the trapezius and deltoid are divided. The vertebral border is then made prominent by drawing the patient's hand over the shoulder on the sound side. The periosteum is divided between the rhomboideus and the infraspinatus, and the infraspinous fossa carefully cleaned. The teres major and serratus magnus are then detached, freeing the inferior angle, which is then lifted up, and the subscapularis muscle is dissected off from below upward. The supraspinous fossa is then cleared, injury to the suprascapular nerve being avoided by lifting it with the periosteum. The remaining part of the bone is cleared, working forward to the neck of the scapula, which is divided with a chain-saw or forceps. The attachments of the acromion to the clavicle, including the conoid and trapezoid ligaments, are then cut and the joint opened. The muscles attached to the coracoid process are divided and the process twisted free. The great risk through the operation is from hemorrhage, especially as the excision is usually undertaken for removal of a sarcoma, under which conditions the vessels are numerous and of large size. It is advisable to have compression over the subclavian artery; and in some cases it may be necessary to make a small incision over the vessel, in order better to control the bleeding. The main vessels may be exposed and ligatured before cutting.

Excision and Resection of the Humerus.—The humerus may be removed in part or as a whole. If the upper part is to be excised, the relation of the musculospiral nerve must be remembered. It passes around posterior to the humerus from its inner side, lies close to the bone in the musculospiral groove, and passes down to the outside of the arm between the brachialis anticus and supinator longus. If, for any reason, the incision must be on the outer side of the arm, it is well first to find the nerve and retract it to the outside before going on with the incision. The incision for excision of the head of the humerus is usually that of Ollier—a straight cut over the surface of the joint, beginning at the acromioclavicular junction and passing over the anterior convexity of the joint for a distance of 3 or 4 inches. The periosteum is saved as much as possible, the joint opened, and the muscular attachments at the tuberosities divided as they are brought into view by rotating the arm. It is advisable at times to leave as much of the tuberosities as possible, as the formation of new bone is then better. The head of the bone is forced out of the incision and the bone sawed across. The best result comes from dividing it at the anatomical neck.

The Lower Portion.—The structures most likely to be injured, and therefore to be avoided, at the lower end are the brachial artery and ulnar nerve. The incision is made between the triceps and supinator longus, avoiding the musculospiral nerve, and the steps of the operation are then similar to those in excision of the elbow. The whole humerus may be resected, care being taken to leave the periosteum, as on it depend the formation of new bone and the usefulness of the arm.

Excision and Resection of the Ulna.—As the ulna is comparatively superficial in its whole extent, it is easily removed. The incision follows its posterior border, and at the upper end runs obliquely upward and outward between the triceps and anconeous muscles. The

subperiosteal method is to be pursued if possible. When the whole bone is to be excised, the upper end and the olecranon are first dissected free, and the bone is then divided at its middle point. This permits removal of the proximal half. The distal portion is then removed. The dorsal branch of the ulnar nerve winds backward beneath the flexor carpi ulnaris about 2 or 3 inches above the wrist, and should be saved when possible.

Excision and Resection of the Radius.—The incision lies on the external surface of the radius, parallel to its long axis. It extends from the styloid process to the radiohumeral articulation. The interspace between the supinator longus and the extensor carpi radialis longior muscles is found. Following through this intermuscular space the radial nerve is found, which runs beneath the supinator longus to about 3 inches above the wrist, where it turns backward and becomes subcutaneous. The supinator brevis is divided and the periosteum separated. The bone is then sawed through in the middle and each piece removed separately. In young persons the restoration of parts after subperiosteal resection of the ulna or radius especially has been good. On the other hand, when the periosteum has not been saved or the epiphyses destroyed, the deformities have been great. For excision of only a portion of the radius an incision along the same line is used.

Excision of the Metacarpal Bones and Phalanges.—To reach a metacarpal bone a longitudinal incision on the dorsum is used. At the first cut the skin alone is divided, as the extensor tendons lie on the dorsal aspect of the metacarpals. These tendons are pulled aside, the periosteum freed, and a curved director slipped under the bone, lifting it up. The bone is then divided with cutting-forceps. The end is seized with bone-forceps and twisted free. If the whole bone is to be removed, the remaining half is dealt with in the same way. Excision of the metacarpophalangeal joint of a finger is apt to leave a flail-like finger. However, excision of the metacarpophalangeal joint of the thumb has given excellent results.

When a phalanx is to be resected, the incision lies on the side of the finger nearer the dorsal than the palmar surface, to avoid the vessels and nerves. To remove a terminal phalanx a U-shaped incision is made, the arms of the U being on the sides of the phalanx, and the curve on the dorsum close to the nail.

Resection of the Bones of the Pelvis.—It is seldom that the attempt is made to excise much of the pelvis. The operation is undertaken usually to remove small areas of bone. However, C. Nélaton reports a case in which he removed the whole ilium, and the patient preserved the power of walking. If the ischium with its descending ramus and the pubis are involved, an incision is made, starting from the genitocrural fold, along the rami of the ischium and pubis to the body of the pubis. The periosteum is lifted from the parts to be removed and the diseased bone cut out. If much of the ilium is involved, the incision follows the crest of the ilium from the posterior superior spine to the anterior superior spine, and then turns sharply downward and backward to the region of the trochanter. The periosteum, reached along the crest of the ilium between the sets of muscles, is raised from the inner surface, extending down into the iliac

fossa, as well as from the outer. As much of the diseased bone as is desired is removed by the chisel or gouge. This operation in the hands of Kocher and Roux has given good results.

Excision of the Coccyx.—The coccyx may require removal in whole or in part for necrosis, fracture, or the painful affection coccygodynia, and as the preliminary step in Kraske's operation for excision of the rectum. After determining the limits of the bone by the finger in the rectum, a longitudinal incision is made over the middle of the coccyx, extending from a little above its upper limits to a little below its tip. If necessary, a transverse cut may be made. The bone is freed from soft parts and the articulation with the sacrum opened, the sacrococcygeal ligaments divided, and the bone cut free, clearing the anterior aspect as it is raised.

Resection of the Shaft of the Femur.—Excisions of portions of the shaft of the femur are very rare, except for the removal of large sequestra. The bone is reached by a long incision on the outer side of the leg. The space between the vastus externus and the short head of the biceps is found and followed down to the bone, which is then entirely freed from the soft parts on all sides if possible, and divided by a saw at its middle. Each end can then in turn be lifted out of the wound, and the proper amount cut away. In the after-treatment extension is necessary for some time, to prevent excessive shortening of the leg.

Resection of the Shaft of the Tibia.—The tibia is more often excised than any other long bone in the body. If the operation is done subperiosteally and the periosteum is not injured, new bone readily forms and a useful leg is obtained. The incision for removal of the diaphysis is made along the subcutaneous surface of the shaft, lying at the upper end behind the tendons of the gracilis, sartorius, and semitendinosus. The periosteum is excised along this same line, and separated all around the bone if possible. A chain-saw is then passed under the shaft and the bone divided, or the diseased portion is chiselled out. In the majority of cases the operation is done to remove sequestra resulting from osteomyelitis or the necrosed fragments following a compound fracture. If the incision must be on the outer aspect of the leg, it should be just a little external to the crest of the tibia. The tibialis anticus should be lifted. The periosteum is not injured. If the posterior surface must be reached, the incision is made along the inner border, the upper end of the cut lying, as already described, behind the tendons of the gracilis, sartorius, and the semitendinoses, and the muscles raised intact with the periosteum. When a portion of the tibia is removed entirely, so that there is a space left between the ends, it is well to excise a corresponding length of the fibula to bring the ends in contact.

Resection of the Fibula.—Excision of the fibula yields very good functional results. There is no particular method of proceeding. A straight incision is made over the portion to be removed, and is continued down to the bone. The periosteum is divided and separated from the bone, which is then divided by a saw and as much removed as is desired. The external popliteal nerve is to be avoided. It follows the posterior border of the tendon of the biceps, winds about the neck

of the fibula, and divides into its two branches. The upper articulation between the fibula and tibia at times communicates with the knee-joint, and therefore opening this articulation should be avoided. When it is necessary to remove the head, it should be chiselled away and a thin plate of bone should be left over the joint. If the whole fibula is to be removed, it is well to take the bone out in two parts, as the peroneal muscles would be cut by a single incision the length of the bone. Therefore a separate incision is made for the lower part over the anterior external aspect of the bone, and another over the upper portion.

Excision of the Bones of the Foot.—The tarsal bones are removed principally for disease, and therefore the methods are largely atypical. Each case has to be considered by itself, and the incision made accordingly. Disease of these bones usually begins in the calcaneo-astragaloid articulation, attacking first the calcaneum, and later the astragalus. Simple scraping away of the diseased portion does not compare favorably with removal through the entire thickness of the bone.

Calcaneum (Fig. 132).—When it is possible, it is advisable to leave the anterior portion of the os calcis, as the reproduction of bone is better in these cases than where the whole bone is removed. The subperiosteal method is to be preferred over those in which the entire bone is cut away. After the subperiosteal method the reproduction of bone is at times sufficient to give a prominent heel, which is very serviceable and quite as firm as the sound one. The method of Faraboeuf is probably the best. The patient is placed on the sound side and the leg supported by a pillow, which gives free access to the diseased foot. The incision begins at the base of the fifth metatarsal, and follows the external surface of the foot, just above the sole, to the heel, which it circles, and then passes forward on the inner side to a point opposite its origin. A second incision runs from this upward along the external border of the tendo Achillis for about 2 inches. The two flaps are raised. The periosteum is divided, care being taken not to injure the peroneal tendons, which lie just anterior to the vertical cut. The periosteum is divided, and with it the attached ligaments are raised, first on the outer and then, after cutting the insertion of the tendo Achillis, on the posterior surface. The anterior part is then freed from its periosteum, and lastly the plantar surface is cleared. The anterior portion is then seized with lion-forceps and cut free as it is dragged out.

FIG. 132.—Resection of the calcaneum.

The operation for removal of the posterior part alone is more sim-

ple. The incision (Fig. 132, *a*) extends to the periosteum, which is separated from the bone and the bone sawed across.

Astragalus.—This bone is excised for irreducible dislocation and caries and for relief of some forms of talipes, and is the first step in excision of the ankle. Two incisions may be made, one internal and one external; or one curving incision may run across the dorsum of the foot. The outer of the two incisions lies just parallel to the peroneus tertius, beginning a little above the level of the articular surface of the tibia. A second cut runs from the middle of this incision backward to just below the tip of the external malleolus. By lifting these two flaps the bone is reached between the peroneus brevis and tertius. By extending and inverting the foot the various ligaments are exposed and cut. A slightly curved incision is then made, running forward and backward from the tip of the inner malleolus. This gives access to the ligaments on the inner side of the foot, which are divided. The foot is again inverted and extended, and the astragalus grasped by forceps and delivered through the outer wound.

When the curved incision across the dorsum of the foot is used the cut should at first be only skin deep. The various tendons on the dorsum of the foot are exposed and drawn aside. The tendon of the extensor brevis is divided, and the structures about the neck and the outer non-articulating surface of the astragalus are cut away. The ligaments within reach are divided. The bone is grasped and drawn out, and the remaining ligaments are cut as they are reached.

Metatarsal Bones and Phalanges.—*Resection or Excision.*—The method of removing the phalanges of the toes corresponds with that of removing the phalanges of the fingers. Lateral incisions are usually employed. The value of the great toe in walking should be remembered, and when a diseased bone is removed from it the periosteum should be left as far as possible, to provide for re-formation of bone. The incision for removing a metatarsal lies along the dorsum. The tendon is retracted to one side and the periosteum divided. The procedure is similar to that for removing the metacarpals. For the first and fifth metatarsals the incision is on the lateral aspect, curving downward.

PLASTIC SURGERY.

Plastic surgery is concerned with the repair of defects or losses of tissue, which may be congenital, or have resulted from disease or injury or from the surgeon's knife in the removal of tumors, etc. By far the greater number of plastic operations are concerned with the replacement of skin-defects, and these only will be discussed in this chapter.

Methods Employed in Plastic Surgery.—Four methods, of which the first three include the great majority of plastic operations, may be employed for the repair of defects. These are: 1. The method of directly approximating the edges by stretching the skin and deeper parts of the wound together, and fixing them by sutures. 2. The method of approximating the edges of the skin after freeing it and the subcutaneous tissue from underlying tissues ("undermining" the edges). This method also allows the use of subsidiary incisions to promote lateral displacement or sliding. 3. The method

of flap-formation, and revolution of the flap into position by twisting the pedicle (the so-called "Indian" method). 4. The method of transplanting a flap from a distant part of the body, as from the arm to the nose, and, after allowing it to unite around the greater part of its margin, severing the pedicle (the so-called "Italian" method).

1. The first method, or **direct approximation of the edges,** may be applied when the gap is small, and is useful for the closure of sinuses or fissured openings. In such cases, of course, careful freshening of the edges is required. When the closure of small raw surfaces is the object, the shape of the surface makes distinct differences as to the applicability of the direct method of closure. An elongated rhomboid or ellipse may, of course, be more easily approximated to a single suture-line than a square or circular surface, which will require stretching of the edges across half the diameter of the surface. A small triangular surface may be easily closed by diminishing all three angles to a point in the center, or, if the triangle have two long sides and a short base, by directly approximating the long sides.

2. **The Method of Lateral Displacement or Gliding.**—This method, which is to be applied whenever direct approximation of edges

FIG. 133.—Repair of a triangular defect (*a b c*) by means of a bilateral incision (*a d* and *b d'*).

would result in disastrous tension, adds to the former method the resources of freeing the flaps and making subsidiary incisions. To **close a triangle,** the line of its base may be continued by an incision,

FIG. 134.—Repair of a triangular defect (*a b c*) by means of a curved incision (*b d*).

and the flap formed by the base and the adjacent side freed and stretched across the gap; or, by continuing the base-line on both ends of the triangle, two flaps may be freed and brought together in the median line (Fig. 133).

The continuation of the base-line may be, under some circumstances, curved rather than straight. The modification known as *von Jaesche's* operation employs the curved incision for this purpose (Fig. 134).

Dieffenbach closed a triangular defect by displacing a quadrilateral flap toward one side of the triangle, or by the displacement of two

FIG. 135.—Dieffenbach's method: *A*, a triangular defect is covered by a laterally displaced flap (*c a b d*); the triangle *b d e* heals by granulation. *B*, the defect (*a b c*) is to be repaired by displacement of the lateral skin, which is mobilized by the incisions *a d e* and *b d' e'*.

quadrilateral flaps toward the middle line (Fig. 135, *A* and *B*). The triangle left by displacement of the flap must heal by granulation or be grafted.

Bürow devised several methods for the closure of triangular gaps, one of the most ingenious of which is shown in Fig. 136. To close

FIG. 136.—Bürow's operation by means of excision of lateral triangles.

the triangle at *a b c*, the incisions *a d* and *b d'* are made, and the flaps *d a c* and *d' b c* are brought together in the middle line. Redundant

FIG. 137.—Repair of a quadrangular defect (*a b c d*) by means of the incisions *a e*, *b e*, *c f*, *d f*.

tissue at the angles may be made by excising the triangles of skin *a d e* and *e' b d'*, and it will be found that when the two sides of the main

triangle are sutured, the subsidiary triangles come together without tension.

A **quadrilateral gap** may be closed by continuation of the longer margins of the wound on both sides of the area to be covered, detachment of the flaps so formed, and suture along the middle line. A single lateral flap may suffice in some cases (Fig. 137).

Letenneur's operation for closure of a quadrilateral gap comprises the displacement across the gap of a flap formed by the incisions shown in Fig. 138. The margin *ef* is sutured to the margin *a d*.

Brun's operation (Fig. 139) is useful in cheiloplasty. The two quadrilateral flaps are swung downward (or upward in case of the lower

FIG. 138.—Letenneur's operation.

FIG. 139.—Brun's operation.

lip) across the denuded area, and their free margins (*e f* and *h i*) sutured in the middle line.

A similar method may be employed for the closure of **large elliptical defects.**

Here two curved flaps, shaped as shown in the figure, are freed and displaced upward so as to close the raw surface. In the method known as *Weber's operation* (also shown in Fig. 140), the flaps *a c d* and *b e f* are formed, the point *c* carried up to *b*, and the margin *a b* sutured

FIG. 140.—Operation for the closure of elliptical defects.

to *a c*. The flap *b e f* is used to close the gap left by the displacement upward of the flap *a c d*.

3. **The method of flap-formation** by derivation of a flap from neighboring tissue by twisting of its pedicle is illustrated by those methods of rhinoplasty by which a flap is derived from the cheeks or forehead (*Indian method*).

4. The fourth method, or derivation of the flap from distant parts which are temporarily approximated until the flap has healed in place, may be illustrated by the *Italian method* of rhinoplasty (Fig. 141) (see page 397), in which the new nose is made from a flap taken from the arm.

For the lining of cavities ordinarily lined with mucous membrane, it may be necessary to employ the reversed flap—*i. e.*, with the skin inward and the raw surface outward. The external skin-surface may be then supplied by swinging in another flap to cover the raw external surface of the former—the double or superposed flap.

FIG. 141.—Italian method of rhinoplasty from the arm, which is immovably secured to the head until union of the flap has taken place (Linhart).

Deformities after Burns.—Operations for the relief of scar-contraction after burns involving the neck, face, and upper extremity are not infrequently required, and are often difficult of performance and not over-satisfactory in results. Especially trying are burns which draw down the lower lip, resulting in inability to close the mouth and in hideous deformity. Cicatricial bands of great breadth or strength may form after burns of the axilla, and prevent raising the arm from the side. Burns on the flexor surface of the fingers may totally disable a hand by reason of cicatricial contraction. Simple division of these cicatricial bands, or even their excision, leaving the resulting raw surface to granulate, is unsatisfactory, as subsequent recontraction takes place, reproducing the deformity. The best results have been attained by the swinging in of ample skin-flaps to cover the raw surface left by excision of the cicatrices. The areas left by raising the flaps may be closed by subsidiary plastics or by skin-grafting.

The procedure known as **Croft's operation** is recommended by Treves as being one of the most satisfactory methods for the prevention of recontraction of these scars. It is performed in two stages. The first stage consists in raising a strap of skin from the integument in the neighborhood of the scar, and after suturing the edges of the skin under the strap, which is left attached at both ends, a piece of rubber tissue is placed beneath the strap to prevent its healing down into place. After two or three weeks, during which time, by frequent and careful dressings, the strap, especially at the ends, has been prevented from healing down, the under surface will be covered with healthy granulations. The second step of the operation, which consists in dividing the cicatricial band until healthy tissues are exposed, then severing the distal end of the strap, swinging it over the raw surface left by dividing the cicatrix, and suturing it in place, may now be performed. The shape of the wound and of the transplant must be fitted as far as circumstances allow, and the edges and under surface of the free end of the transplant trimmed and cleaned up so as to favor primary union. The flap, which has become narrow and rounded, will flatten and stretch as it heals in place.

Rhinoplasty.—The term rhinoplasty is properly applied to restoration of part or the whole of the structures of the nose which have been

FIG. 142.—Rhinoplasty: *a*, lateral flap; *b*, von Langenbeck's method.

FIG. 143.—Denonvillier's method of rhinoplasty.

destroyed by disease or injury. Simple integumental defects, such as are left after operations for epithelioma, may be closed by granulation or skin-grafting, and do not require plastic operations for their repair. Rhinoplasty may be simple of performance and satisfactory in result, or difficult and unsatisfactory, according to the amount of structures which give support and prominence to the nose—*i. e.*, the septum and nasal bones—which have been destroyed.

A **defect of the ala** involving the lower portion or the whole of the ala may be closed by lifting a flap with a pedicle from the cheek close to the nose and swinging it inward so as to close the gap. This flap must be long enough for the lower end to be turned in, giving a lining of skin to the new ala, and preventing cicatricial contraction (Fig. 142, *a*).

Von Langenbeck's method consisted in taking the flap of skin from the opposite side of the nose, with the pedicle near the root of the nose, and swinging it across so as to cover the defect.

FIG. 144.—Formation of one nostril from the skin of the other (after Langenbeck).

The *method of Denonvillier* consisted in employing a triangular flap taken from the same side of the nose, having its pedicle at the center of the lobe of the nose. The triangular flap marked out by the incisions as shown in Fig. 143 is dissected up clean from the bone and cartilage, and rotated downward around its pedicle till the gap is filled. The defect left above it is closed by granulation or grafting. It has the advantage of furnishing a border that is already at least partially lined with epidermis.

Other methods have been described by which an ala is restored by taking a flap from the septum and attaching it to the margin of the alar defect with its mucous surface out. This operation was first described by Michon. It would seem to possess the two disadvantages of placing mucous membrane instead of skin on the outer surface of the nose, and of providing no epidermoid lining for the new ala.

A **defect of the columna** may be restored by taking a vertical flap from the middle of the lip, having its pedicle above, twisting the pedicle so as to bring its cutaneous surface downward, and suturing the raw surface to the carefully cleaned lower margin of the portion of the septum. In order to avoid the deformity due to the twisting of the pedicle, Desprès took the flap obliquely from the upper lip, so that it had to be twisted only half so far. Sédillot devised the procedure of taking the flap the whole thickness of the lip, taking the skin off the outer surface, and turning it directly upward, so that the lower border of the new columna was covered with mucous membrane instead of skin. It is stated that in time the mucous membrane loses its red color and assumes the appearance of ordinary skin.

In **loss of the entire septum and nasal bones,** resulting in the most extreme variety of sunken nose, Dieffenbach and Malgaigne divided the nose into three portions by two vertical incisions carried from within, clear out through the skin close to the septum, and two lateral incisions in the chinks parallel and close to the sides of the nose and surrounding the ala. The cheeks were dissected up through three lateral incisions, the upper lip freed from the upper jaw, and the lateral nasal flaps completely dissected up. The columna was lengthened by lateral incisions, and the center and sides of the nose passed into place and fixed by harelip-pins passed transversely from side to side of the nose. The margins of the wound were sutured to the free margins of the incisions in the cheeks, which were also pinched up toward the nose and held there by long pins passing through the inner portion of the cheeks and through the nose.

Ollier performed for this deformity an osteoplastic operation, taking a triangular flap with its apex 1½ centimeters above the eyebrows, and its base constituted by the inner portion of the nose and the cheeks, the periosteum being raised with the frontal portion of the flap. The right nasal bone was chiselled off, displaced downward, and used for a central support. The left nasal bone had been destroyed by disease. The whole flap was then displaced downward, and the lower part laterally compressed in order to raise the bridge, and kept up by bringing in the cheeks, which had been loosened at the sides, and supporting them with pins.

Verneuil employed a method consisting of the superposition of flaps, in order to raise the bridge of the nose. A flap was cut from the median line of the forehead, as shown in Fig. 145. A cut along the center of the bridge of the nose, and lateral cuts at its upper and lower ends, allowed the reflection of skin-flaps from the nose and cheeks. The flap from the forehead was then turned directly downward, so that its skin-surface lined the nasal fossa, and the lateral flaps drawn in and sutured over it in the middle line.

Indian Method.—A model of a nose suited to the case is made of

wax, plaster-of-Paris, or other plastic material, and a pattern of paper or cloth made of its surface. The outline of this pattern is marked on the forehead; its apex being immediately above the nose, its base will reach the hair-line. It may be necessary to shave the head for an inch from the hair-line in order to obtain skin for the columna. The frontal

FIG. 145.—Rhinoplasty for sunken nose by superposed flaps (Verneuil).

flap (Fig. 146) should be one-third longer and one-third broader than the space which it is desired to fill. In order to avoid encroaching on the hairy scalp, the flap may be taken obliquely from the forehead.

FIG. 146.—Formation of flap at the root of the nose, and incision for Langenbeck's model upon the forehead.

The oblique flap will require less twisting of its pedicle. Twisting of the pedicle is favored by carrying one of the terminal incisions further downward than the other. The edges of the gap, and of such osseous and cartilaginous structures as remain, which should, of course, be scrupulously spared, are freshened, and the flap brought down and sutured into place, being supported, if necessary, by pins and by the insertion of tubes and plugs in the nostrils. After the flap has healed in place the pedicle may be divided and suitably trimmed. The results attained by this operation will depend in large measure on the amount

of septal and alar cartilage available to support the flap. Otherwise the result will be a mere shapeless curtain hanging across the gap.

In managing the pedicle considerable skill is required to avoid such tight twisting as may result in gangrene of the flap.

Ollier's Osteoplastic Method.—In a case in which lupus had destroyed the tissues of the end of the nose to the extent shown in Fig. 147, Ollier made two incisions from the middle of the forehead, 2 inches above the eyebrows, downward to the cheeks, just outside the borders of the alæ. This flap included the periosteum in its upper position, and on arriving at the nasal bones Ollier chiselled one of them from its attachments and included it in the flap. The flap was then brought directly downward in front of the gap, so that the upper end of the freed nasal bone came against the lower end of the fixed nasal bone, to which it was sutured with silver wire, thus making a continuous bony bridge. In order to furnish a septal support, the cartilaginous septum was divided from before backward and downward, and this portion thus separated was brought down with the flap till it rested on the remains of the lower part of the original septum.

FIG. 147.—Rhinoplasty: Ollier's osteoplastic method.

Italian Method.—The principle of this method, with which the name of Tagliacozzi is identified, consists in supplying material for the new nose from the arm. It is suitable in certain cases in which the Indian method is inapplicable—those, for instance, where the forehead is covered with scar-tissue, so that a flap cannot be taken from it. It is also possible to provide tissue more generously—an important advantage when the flap is taken from the arm rather than from the cheeks or forehead. Tagliacozzi cut his flap from the front of the upper arm, with the apex upward and the broad pedicle 2 inches above the cubit flexure. The wound was sutured under the raised flap, and the under surface of the flap carefully prevented from healing down by dressings of oiled silk and ointments to promote suppuration. After the under surface of the flap had partly cicatrized the arm was brought up against the nose and held by a helmet, corset, and suitable straps (Fig. 141), and the apex and sides of the flap sutured in place in the freshened gap. After the flap had healed into its new bed the pedicle was divided and the columna, alæ, etc. fashioned from its lower border.

Later operators have modified these procedures by suturing the flap in place immediately or dissecting it up without waiting for granulation, and by taking the flap from the forearm instead of the upper arm.

The results from rhinoplasty in cases in which the alæ and projecting parts of the septum are destroyed are, on the whole, so unsatisfactory that the alternative of wearing an artificial nose, which can now be very skilfully made, and by means of spectacle-bows attached to the face so as to escape detection by most observers, is well worth careful consideration.

CHAPTER XIII.

MINOR SURGERY.

It is the province of a treatise on Minor Surgery to describe the common instruments and materials of surgery and their uses, the making of incisions, the arrest of hemorrhage, the closure and dressing of wounds, the performance of the simpler operations, the application of splints and bandages, and many of those manipulations which are employed in the care of a great variety of surgical cases and in different regions of the body. In view of the fact that many of these subjects have been discussed in other portions of the work, it will be sufficient for this chapter to present a consideration of the points not elsewhere touched upon. It is well to remind the reader that the term minor is by no means synonymous with unimportant, and that a correct knowledge of minor surgery is absolutely necessary in the management of even a major operation and in the subsequent care of the case.

BANDAGES.

Bandages are applied to retain splints or dressings, to make compression, to afford support, or to correct deformity. They are composed of various materials and are of different shapes and sizes. Among the materials used for the purpose of making bandages may be mentioned gauze, flannel, calico, silk, linen, elastic webbing, india-rubber, and unbleached muslin. Whatever substance is used must be strong enough to permit of firm application, and must be supple enough to allow of neat adjustment to the part. Calico is a very poor material, being too light and apt to tear and crease. Linen and silk are expensive. Gauze is useful in many cases. It is light, can be neatly adjusted, is thin, porous, soft, and makes even compression. One of its chief uses is to retain dressings upon a wound, and when employed for this purpose it may be used dry or may be moistened with an antiseptic solution. A wet gauze bandage can be applied with great neatness, but must be put on more loosely than a dry bandage, because it contracts on drying, and, if firmly applied while wet, may become dangerously tight when dry. The rubber bandage of the form known as Martin's bandage is used in the treatment of swollen joints, varicose veins of the leg, ulcers and swelling of the lower extremity. In these conditions it is applied before the patient arises in the morning, and is removed after he has gone to bed at night. After it has been taken off it should be washed with soap and water, dried with a towel, and [illegible] rubber bandage [illegible] treat [illegible] bandage is [illegible] compression, [illegible]

the part warm, and absorbs moisture. It is used particularly in the treatment of sprains, rheumatic or gouty joints, and varicose veins of the leg. It is employed to surround a part which is to be covered with a plaster-of-Paris dressing, and is very useful as a material for T-bandages and abdominal binders. Ordinarily, bandages are made of unbleached muslin which has been washed, dried, and torn into strips, each strip being seamless and clear of selvage. But one strip should be employed to make a bandage, because, if two strips are sewed together, a seam is formed, and such a seam will crease the skin. Selvage must be removed, because it, too, will crease the skin.

Bandages vary in width and length. The following dimensions for different regions are given by Wharton and Curtis: Bandages for the hands, fingers and toes, 1 inch wide and 3 yards long; for the extremities in children, 2 inches wide and 6 yards long; for the extremities in adults, 2½ inches wide and 7 yards long; head-bandages, 2 inches wide and 6 yards long; thigh- and groin-bandages, 3 inches wide and 9 yards long; trunk-bandages, 4 inches wide and 10 yards long.

To make a bandage the material can be rolled into a cylindrical form by the hand or by a machine. Material so rolled constitutes a roller bandage. In order to roll a bandage by the hand, one end of the material is folded to the extent of 6 inches. This is folded upon itself again and again until a firm center or core is constructed, and over this stem the bandage is rolled (Fig. 148). The manipulation of rolling is carried out as follows: The extremities of the stem are grasped between the thumb and fingers of the left hand, and the free extremity of the bandage between the thumb and index finger of the right hand. The bandage is rolled with the left hand and kept tight, in order to secure firmness, with the right hand. In a well-rolled bandage it is impossible to push out the core with the finger. A bandage-rolling machine is very largely used in hospitals. A bandage rolled from one end only is called a single-headed roller; a bandage rolled from each end toward the center is called a double-headed roller. The single-headed roller is the one usually employed. Its free end is known as the initial extremity; its cylinder is called the body, its hidden end the terminal extremity.

FIG. 148.—Rolling a bandage by hand.

Bandages are named from their application (circular, spiral, reversed, etc.), from their uses (suspensory of the breast), from their situation (crossed of the angle of the jaw), from their shape (figure-of-8), and occasionally after the person who devised them (Barton, Gibson, Desault, Velpeau).

General Rules for Bandaging.—The surgeon faces the patient, places the outer surface of the free extremity of the bandage upon the part, and retains it by the fingers until it is fixed by several circular turns. The roller is held between the thumb and fingers of the right hand, so that it will easily unroll. The turns of the bandage must be

firm, smooth, even, applied so as to make equal pressure, and never tight enough to cause discomfort. In taking the bandage around a joint, the part should first be placed in the position it is to be retained in after the dressing is complete, because to alter the position after the bandage has been applied may lead to injurious pressure. When the part is covered, the bandage is completed by two circular turns, and the terminal end is fastened by a safety-pin to the turns underneath. A tight bandage causes discomfort, possibly severe suffering, and may even lead to gangrene. If it is necessary to apply a firm bandage above the periphery of the limb, the peripheral parts should be included first, in order to prevent swelling. If the bandage tends to slip, the edges or crossing should be stitched, or the bandage should be covered with strips of adhesive plaster. In order to remove a bandage, it may be cut with bandage-shears, or the pin may be removed from the termination and the material unwound, the unrolled part being grasped in the hand and transferred from one hand to the other.

The Elementary Forms of Bandages.—1. **Circular.**—Circular turns are made round and round a part, but they neither ascend nor descend, and each turn exactly overlies its predecessor. Such a bandage is employed to retain a dressing on the wrist, neck, or forehead, or to compress the veins before the performance of venesection or transfusion of saline fluid.

2. **Oblique.**—Oblique turns are carried up the extremity in the manner of a stripe on a barber's pole, each turn having between it and the preceding turn an uncovered area of skin. The oblique bandage is used to lightly retain thick and loosely applied dressings for burns and scalds.

3. **Spiral.**—In this method the bandage is carried up a part, each turn overlying one-third of the preceding turn. This bandage is often applied to the chest and abdomen, but is not used upon the extremities, as the size of these parts becomes progressively greater toward the body, so that a spiral bandage would be tight at the upper border of each turn and loose at the lower border, would make unequal pressure, and would tend to slip.

4. **The Spiral Reversed.**—The reverse corrects the inequality existing in the spiral, and by means of reverses a conical extremity can be evenly bandaged. A reverse is made in the following manner (Fig. 149): If the initial extremity has been fixed by circular turns, the bandage is carried up the limb obliquely. The thumb of the surgeon's left hand holds the unrolled turn to keep it secure, the roller is pulled out until there are 6 inches of free bandage between the thumb and the cylinder, and this free bandage is permitted to be slack. The supinated hand holding the roller is carried transversely under the limb, and traction is made to cause the reverse to apply itself accurately to the surface. All the reverses should be in line. Reverses should not be made over joints or bony prominences.

5. **The Spica.**—The spica is used to cover the shoulder, the groin, the thumb, and the foot. Each turn crosses its predecessor so as to cover two-thirds of it, and the turns take the form of the Greek letter lambda (Λ), and when applied resemble the leaves of an ear of corn.

6. **The Figure-of-8.**—This is especially useful in bandaging joints,

and is also employed to bandage the neck and axillæ and the occiput and jaw. The turns resemble in shape the figure 8.

7. **Recurrent.**—The recurrent bandage is used to dress the head and amputation-stumps. The part is covered by a series of turns, each

FIG. 149.—Manner of making the reverse.

one of which recurs to its point of origin, and the recurrent turns are covered by spiral or spiral reversed turns.

Forms of Compound Bandages.—1. **The single T-bandage** consists of a vertical piece which is stitched or pinned to a horizontal piece. It is used for the perineum, the head, the anus, and the scrotum. To apply it to the perineum, the horizontal piece is fastened around the waist, with the vertical piece behind. The ends of the horizontal piece are pinned together, the vertical piece pulled between the thighs, the end torn into two tails, and each tail taken to one side of the genitalia and pinned to the waist-piece.

2. **The double T-bandage** is used to hold dressings upon the back or chest. The broad piece surrounds the chest and the narrow pieces pass over the shoulders as suspenders.

3. **The many-tailed bandage** is made of muslin or flannel. The ends are torn almost to the center of the material into as many tails as may be required. Surgeons frequently use the many-tailed bandage to retain dressings upon the abdomen. In order to prepare this abdominal bandage, a piece of flannel $1\frac{1}{2}$ yards long and 2 feet wide is torn into 8 tails at each end, the center is applied to the patient's back, the ends are brought in front, overlapped successively, and pinned in place.

FIG. 150.—Four-tailed bandage of the head.

4. **The four-tailed bandage** (Fig. 150) is used chiefly to dress fractures of the jaw and to hold dressings upon the scalp or chin.

5. **Mayor's Handkerchief-dressings.**—These dressings were devised by Mayor of Geneva. He showed that if a square piece of muslin is taken, different methods of fold-

ing and application will enable one to dress satisfactorily various regions of the body. A square piece folded upon itself once or twice constitutes the oblique form; bringing the two distinct angles together forms the triangle. If the point of the triangle be taken to the base and the material be folded a number of times, the *cravat* is formed. Twisting the cravat forms the *cord*. The handkerchief-dressing is useful to cover the head, the groin, or a joint, and to support the breast or the testicles. It is particularly useful in emergencies and in military practice.

Slings.—A sling can be made from an ordinary roller bandage, by means of which the extremity is hung to the neck. A better form of sling for the forearm is made from a handkerchief, and is called the *triangular sling*. A piece of muslin a yard long is taken and folded into a triangle. This triangle is carried under the limb, with its apex projecting behind the elbow, the portion which comes from under the limb being carried over the opposite shoulder; the other portion is lifted and carried over the near shoulder, and the ends are fastened together behind the neck. The apex is pulled forward from behind the elbow and pinned to the anterior portion. This sling supports the entire forearm and hand.

Fixed Dressings.—Fixed or solid dressings are used in the treatment of fractures, injuries and diseases of joints, after operations upon bones, and for the treatment of certain deformities. In order to make a fixed dressing, some material which will give firmness is placed in the fabric constituting the bandage, either before the application of the bandage or after it has been applied. Dressings may be rendered solid by the use of plaster of Paris, starch, silicate of soda or of potash, glue and zinc oxid, paraffin, gum and chalk, or celluloid. The most generally useful is the plaster-of-Paris dressing, which differs from the other materials in the fact that it does not contract as it hardens, but expands a little.

Plaster Bandage.—This is best applied after Sayre's method, the dry plaster being incorporated into gauze or crinoline before the bandage is applied. The best calcined plaster of Paris is necessary. The extremity is bandaged evenly and lightly with flannel, and cotton is placed over the bony prominences; gauze bandages, each one being 5 yards long and 3 inches wide, are infiltrated with dry plaster as they are rolled up. They are usually kept ready for use, wrapped in waxed paper and stored in a glass jar. If the bandage has been prepared for some time, it is best to heat it in an oven before attempting to employ it. The bandages are dropped into tepid water and should be entirely submerged. If it is desired to have them set quickly, the water should contain a little salt; if they are to set slowly, it should contain a little stale beer. The bandage is ready to use when bubbles of air have ceased to be given off from it. It is then removed from the water, squeezed, and applied. It is applied from the periphery upward, evenly, firmly, but never tightly. Three or four thicknesses are usually sufficient, but if it is desirable to render the dressing particularly strong, pieces of wood, tin, zinc, or pasteboard may be placed between the folds of the bandage as it is being applied. A plaster bandage becomes firm in fifteen or twenty minutes, but it should not be trusted to bear weight for several hours. After it is dried, it is a good plan to varnish it in order to prevent chipping (Bryant).

Gigli has devised a useful method of applying the plaster bandage.

After putting the flannel and cotton around the limb, this surgeon places a layer of moist parchment paper over the flannel upon the front of the limb, and upon it a thick cord greased with vaselin is laid, in the direction one would need to saw to open the plaster; over this the plaster is applied. When in the course of time we are ready to remove the plaster, the cord—ends of which project beyond the bandage—is loosened, and one end is tied to a fine steel wire which has been nicked transversely at intervals by means of a file. The wire is drawn through the cavity which was previously occupied by the cord. Each end of this wire is wound around a piece of wood which is to serve as a handle, and the plaster is then readily sawed through from within outward.

It is occasionally necessary to apply what is known as the interrupted plaster dressing (Fig. 151), the interruption in the plaster enabling the surgeon to reach a wound and dress it readily while the part is perfectly immobilized. In order to apply such a dressing, a

FIG. 151.—Interrupted plaster-of-Paris dressing.

piece of wood or iron is placed underneath the extremity, running above and below the level of the point which is to be left open, and fixed thus with a few turns of the plaster bandage at its extremities. A piece of tin or iron is bent into a large loop, the ends of this piece

FIG. 152.—Trap-door dressing.

are laid upon the surface and caught in the turns of the plaster bandage. It may be necessary to use one, two, or three of these brackets, according to the degree of firmness which is desired. A good many surgeons in applying an uninterrupted plaster dressing lay upon the front surface of the limb, before applying the plaster, a piece of zinc, and when it

becomes necessary to remove the plaster, this zinc protects the limb from injury. In some cases a plaster bandage is applied, is cut down the front while soft, and is subsequently flanged open. Such a dressing can be removed whenever necessary, and yet gives excellent support. It can be retained firmly in place by adhesive strips and tapes, by applying an ordinary bandage outside of it, or by putting eyelet-holes in the edges and lacing it up like a shoe. Instead of making a bracketed splint, a trap-door may be cut in the plaster dressing directly over the area which the surgeon afterward desires to reach (Fig. 152). The methods of applying the plaster jacket and the jury-mast will be presented in the articles upon the Surgery of the Spine. A plaster bandage can be removed by splitting it with a knife while it is still moist, by sawing it when it is dry with Hunter's saw, or by cutting it with one of the various forms of plaster-cutters. It is best, in applying this bandage originally, to use Gigli's method, which renders the subsequent removal a most simple matter.

Starch Bandage.—The starch bandage (known also as Seutin's bandage) was used extensively before the invention of the plaster bandage. The starch is mixed with cold water until it is of a creamy consistency, and boiling water is added until the mixture is mucilaginous. The extremity is bandaged with flannel, over which a gauze bandage is applied. This bandage must be shrunk before application, as otherwise it will make undue contraction as it dries. The starch mixture is rubbed into the gauze bandage, and another bandage is applied; more starch is rubbed in, and so on until the extremity is covered with a sufficient thickness. In some cases pieces of pasteboard are added to give additional solidity. This bandage dries in about thirty-six hours.

The Silicate-of-soda Bandage.—This material is usually spoken of as soluble glass. Silicate of potassium can be used equally well. The extremity is bandaged with flannel, and over this are applied several layers of a gauze bandage. The silicate is rubbed in with a brush, another gauze bandage is applied, more silicate is rubbed in, and so on until a sufficient thickness is obtained. It requires twenty-four hours to dry. In order to remove it, the extremity covered with the bandage should be placed in warm water and the dressing cut with scissors.

Gum-and-chalk Bandage.—This material is prepared by making it into a paste by the addition of boiling water. It is applied like the starch bandage, is more solid than is that dressing, and becomes hard in five or six hours.

Glue Bandage.—This was devised by De Morgan. French glue is soaked in cold water, heated in a glue-pot, and applied like the starch bandage. The addition of $\frac{1}{4}$ part of methylated spirit greatly accelerates the drying process. The late Dr. Levis was accustomed to mix oxid of zinc with the glue.

Paraffin Bandage (Tait's Bandage).—Paraffin is a material which is impenetrable by the body-secretions. It melts at 105° to 120° F. The bandage is passed through the melted paraffin as it is being applied. This bandage becomes solid in about ten minutes.

The Celluloid Bandage.—This is strongly commended by Landerer and Kirsch.[1] It is made by saturating mull bandages in a solution of celluloid in acetone. The celluloid is cut into small pieces; a glass jar is filled one-quarter full of these pieces, and is then filled up with the acetone and the lid put on. At intervals the mixture is stirred with a glass rod. The bandage is applied over a plaster cast of the part, which is bandaged with flannel. Over this a mull bandage is applied. By means of the hand gloved with leather, the celluloid gelatin is applied to the mull, another mull bandage is applied, more celluloid gelatin is applied, and so on. The outer layer consists of celluloid. From 4 to 10 layers may be necessary according to the requirements of the case. Within one and one-half hours the dressing is firm enough to be fitted upon the person, and in four hours it is completely dry. This bandage is cheap, is light, and is not affected by the body-secretions.

Bandages of Special Regions.—***Spiral Reversed Bandage of the Upper Extremity*** (Fig. 153).—This bandage is begun by making a circular turn around the wrist and a second turn to hold the first. It is then carried obliquely across the back of the hand to near the

[1] *Centralbl. f. Kinderheilk.*, 1896, Bd. i., S. 307.

extremity of the fingers, and ascends the hand to the root of the thumb by several spiral turns; the wrist is covered by ascending figure-of-8 turns, the forearm is covered by spiral reversed turns, the elbow-joint by figure-of-8 turns, and the arm by a series of spiral reverses. The bandage is terminated by two circular turns which are pinned to each other.

FIG. 153.—Spiral reversed bandage of the upper extremity.

Spiral Bandage of all the Fingers, or the Gauntlet (Fig. 154).—Two circular turns are made around the wrist; the bandage is carried obliquely across the back of the hand to the root of the thumb, and is taken to the tip of the thumb by spiral turns. The thumb is covered in by ascending spiral turns, and the bandage is returned to the wrist. Each finger is covered in the same manner, and the bandage is terminated by two circular turns about the wrist.

Spiral Bandage of the Palm or Dorsum of the Hand; the Demi-gauntlet (Fig. 155).—This bandage is of but limited utility. It must not be applied tightly, as it makes considerable pressure at the roots of the

FIG. 154.—Gauntlet bandage.

FIG. 155.—Demi-gauntlet bandage.

fingers, although it leaves the fingers free. If the wish is to cover the palm, the bandage is begun with the patient's hand supinated; if the desire is to cover the dorsum, it should be started with the hand pronated. Two circular turns are made around the wrist; the bandage is

caught around the root of the thumb and taken back to the point of origin. Each finger is covered in the same manner, and the bandage is ended by a series of ascending figure-of-8 turns about hand and wrist.

Spica Bandage of the Thumb (Fig. 156).—This is begun at the wrist, and is taken to the end of the thumb in the same manner as is the

FIG. 156.—Spica bandage of the thumb.

gauntlet bandage. A series of ascending spica turns are made between the thumb and wrist, each turn overlying two-thirds of the previous turn. The bandage is terminated by two circular turns at the wrist.

Selva's thumb-bandage (Fig. 157) covers the entire thumb. The terminal end of the bandage is placed on the outside of the second phalanx of the thumb, near to the base of the phalanx. The bandage

FIG. 157.—Selva's thumb-bandage.

is then carried over the palmar side of the pulp of the last phalanx to the inner side of the second phalanx, this turn being held temporarily in place by the surgeon's left thumb and index finger. The roller is taken back as a recurrent to its place of origin, is made to overlap the preceding turn, and is placed as much as possible on the dorsum. It is then carried over the terminal phalanx, and is turned around the tip, the loop crossing over the center of the nail. Ascending spica turns are now made over the dorsum of the hand and over the palm, returning to the phalanx.

Spiral Reversed Bandage of the Lower Extremity (Fig. 158).—Two circular turns are made just above the malleoli, and an oblique turn is carried across the dorsum of the foot and the metatarsophalangeal articulation. A circular turn is now made, and the foot is covered with ascending spiral reversed turns. The bandage returns to the ankle as a figure-of-8, ascends the leg by spiral reversed turns, covers the knee

by a figure-of-8, ascends the thigh by spiral reversed turns, and terminates by two circular turns.

Bandage of the Foot, Covering the Heel (*American Bandage of the Foot*) (Fig. 159).—The bandage is begun in the same manner as a spiral reversed bandage of the lower extremity. After the foot is well covered by ascending spiral reversed turns, the bandage is carried around the point of the heel and is returned to the instep. From this point it is carried under the sole of the foot, around the back of the ankle-

FIG. 158.—Spiral reversed bandage of the lower extremity.

joint, down the side of the heel, under the heel up to the instep, around the ankle in the opposite direction, down the opposite side of the heel, under the heel and up to the instep. The roller is carried to above the malleoli, and the bandage is terminated by two circular turns.

Bandage of the Foot, not Covering the Heel (*French Method*).—

FIG. 159.—Bandage of the foot, covering the heel.

FIG. 160.—Spica bandage of the foot.

This has already been set forth in the description of the spiral reversed bandage of the lower extremity.

Spiral Bandage of the Foot, Covering the Heel (*Ribbail's Bandage*, or the *Spica of the Foot*, Fig. 160).—A bandage identical with the ascending spiral reverse of the lower extremity is applied until the metatarsus is well covered. The bandage is carried parallel with the margin of the foot, back along the inner margin or the outer margin (according as to whether we are dealing with the left foot or the right), around the pos-

terior portion of the heel, forward along the opposite edge of the foot; cross the original turn at the median line of the dorsum of the foot, where a number of these turns are made and caused to ascend, each turn covering two-thirds or three-fourths of the previous turn. The bandage is terminated by circular turns about the ankle.

Crossed Bandage of Both Eyes, or Figure-of-8 of Both Eyes (Fig. 161).—A circular turn is made around the forehead from right to left. The second turn is applied to hold the first, and then the bandage is carried downward over the left eye, under the left ear, around the back of the neck, upward under the right ear, and over the right eye. These turns are repeated so as to ascend, and the bandage is terminated by a circular of the forehead.

Borsch's Eye-bandage (Fig. 162).—A narrow bandage is laid along the head so that one end will hang in front of the sound eye and the

FIG. 161.—Crossed bandage of both eyes.

FIG. 162.—Borsch's eye-bandage.

other down to the back of the neck. A circular bandage is applied over this strip so as to cover both eyes; the posterior portion of the narrow strip is pinned to the circular turn at the occiput, while the lower end of the anterior portion of the narrow strip is lifted and pinned to the same strip further back. The lifting of the narrow strip raises the bandage away from the sound eye.

Barton's Bandage (*Figure-of-8 of the Jaw and Occiput*, Fig. 163).—The initial extremity of the bandage is placed below the inion, and a turn is carried over the right parietal bone, across the vertex, down the left side in front of the ear, under the chin, up the right side in front of the ear, across the vertex, and over the parietal bone to the point of origin. A turn is now taken forward along the right side to the jaw and backward along the left side of the jaw to the nape of the neck. These figure-of-8 turns are repeated as often as may be necessary for firmness, and the bandage is finished by circular turns around the forehead. After Barton's bandage has been applied, the ears lie in uncovered triangles.

Gibson's Bandage (Fig. 164).—Three vertical turns are made around the head and jaw, in front of the ears. A half-turn is taken in the

bandage just above the level of the ears, and the turns are carried horizontally around the forehead and occiput three times. The bandage is then dropped to the nape of the neck, and three horizontal turns are taken around the neck and jaw. The bandage is terminated by

FIG. 163.—Barton's bandage.

FIG. 164.—Gibson's bandage.

carrying a half-turn upward and forward from the nape of the neck and along the vertex to the forehead. It is then pinned at its origin, and also over the forehead. It is well to pin or stitch the points of crossing.

Crossed Bandage of the Angle of the Jaw (*Oblique Bandage of the*

FIG. 165.—Crossed bandage of the angle of the jaw.

FIG. 166.—Spica bandage of the groin.

Jaw, Fig. 165).—A circular turn is made around the forehead toward the affected side, and a second turn is applied to hold the first. The

bandage is then carried to the back of the neck, forward under the ear of the sound side to the under surface of the jaw, and is then taken upward in front of the ear of the injured side. A series of turns are now made in front of the ear of the injured side and back of the ear of the sound side. The turns which are in front of the ear progressively advance, while those which are back of the ear remain on the same level. In order to terminate the bandage, it is carried back under the ear of the injured side to the nape of the neck, and then two circular turns are taken around the forehead.

Spica of the Groin (*Figure-of-8 of the Thigh and Pelvis*, Fig. 166).—For the double spica two circular turns are made from right to left around the waist. The bandage is carried downward over the front of the right groin, around the back of the thigh, upward over the front of the right groin and around the waist, downward over the front of the left groin, around the back of the thigh, up over the front of the left groin, and around the waist. A map of the bandage is thus laid out, and the following turns ascend, each one overlying one-third of its predecessor, the bandage being completed by a circular turn around the waist. It is needless to describe the single spica, as it is obvious that it is caught back of but one thigh.

Spica of the Shoulder (Fig. 167).—A circular turn is made around the upper arm, followed by several spiral reversed turns. From behind forward the bandage is carried over the shoulder, across the front of

FIG. 167.—Spica bandage of the shoulder.

FIG. 168.—Figure-of-8 bandage of the neck and axilla.

the chest into the opposite armpit, and is returned across the back at the posterior aspect of the shoulder. A series of ascending turns are thus applied.

Figure-of-8 bandages of the neck and axilla, and of the chest, and of the breast are shown in Figs. 168–170.

Velpeau's Bandage (Fig. 171).—The hand of the injured side is placed upon the shoulder of the sound side, and the elbow is laid against the chest. It is well to interpose some lint or cotton between

the elbow and the chest. The bandage is begun at the axilla of the sound side posteriorly. It is carried over the back, the shoulder of the injured side, down the front of the arm, under the arm just above the

FIG. 169.—Posterior figure-of-8 bandage of the chest.

elbow, returning to its point of origin. The second turn is applied exactly over this one to hold it in place, but on reaching the axilla with this second turn the bandage is taken directly across the back and

FIG. 170.—Suspensory and compressor bandage of the breast.

around the chest, including the arm. Each alternate turn is now carried over the injured clavicle, and each alternate turn is made to encircle the arm and body, the clavicular turns passing progressively forward, the arm- and body-turns regularly ascending.

Desault's Apparatus.—This apparatus consists of three rollers, a pad, and a sling. The pad, which is wedge-shaped, is placed in the axilla of the injured side, its base being upward. The first roller is a spiral of the chest (Fig. 172), which holds the pad in place.

FIG. 171.—Velpeau's bandage.

The second roller binds the arm to the side over the pad (Fig. 173), and, by throwing the shoulder out, corrects the inward deformity of the fractured clavicle. The third roller is

FIG. 172.—Desault's bandage, first roller.

started under the axilla of the sound side anteriorly. It crosses the chest to the shoulder of the injured side, is carried down back of the arm, around the elbow, and upward on the

front of the chest to the point of origin. It is now carried through the axilla to the back, upward across the back and shoulder of the injured side, down the front of the arm, around

FIG. 173.—Desault's bandage, second roller.

the elbow, and across the back to the axilla of the sound side. When these turns have been applied, it will be observed that they leave uncovered two triangular spaces front and back, which are spoken of as the anterior and the posterior triangles. The third roller of

FIG. 174.—Desault's bandage completed.

Desault corrects the downward and forward deformity of the fracture of the clavicle. After the third roller has been applied the hand is hung in a sling (Fig. 174).

Recurrent Bandage of the Head (Fig. 175).—Two circular turns are carried around the forehead and head. When the middle of the forehead is reached, a half-turn is made and the bandage is carried to the occiput. Another half-turn is made, and the bandage is carried forward to the forehead, so as to cover a portion of the preceding turn. These recurrent turns are applied until the head is covered, and while they are being applied, an assistant catches them at the forehead and occiput. When the head is covered, the bandage is terminated by two circular turns around the forehead and occiput, applied firmly and holding the ends of the recurrent turns. It is well to carry a turn or two around the head and chin, and to pin these vertical turns to the horizontal forehead turns.

FIG. 175.—Recurrent bandage of the head.

Recurrent Bandage of a Stump.—Two light circular turns are taken around the root of the stump. The stump is covered by recurrent turns exactly as was the head. A light circular turn is made around the root of the stump, an oblique turn is carried to the top of the stump, and an ascending spiral reverse bandage is applied, which is terminated by two circular turns.

Splints.—A splint is a firm material applied to an extremity in order to secure immobilization. Splints are of various shapes and sizes, suitable for different injuries in particular regions. They may be made of wood, plaster of Paris, felt, leather, binders' board, zinc, tin, copper, etc. Before a splint is applied, it must be well padded, especially at the points which will come in contact with bony prominences. Pads are made of cotton, oakum, or wool. They reach beyond the ends and over the sides of the splint, and are held in place by tapes or bandages. A splint should be applied firmly, but never tightly. It is a wise precaution in applying a splint to the forearm to leave the ends of the fingers in view, and in applying a splint to the leg to leave the toes in view. The condition of the circulation in the digits is a gauge of the state of the circulation in the limb. A splint is held in place by bandages, and when it is desired to remove the splint, the bandage is first cut loose with shears. The use of special forms of splints is considered in various sections of this work.

Adhesive Plaster.—This is a very useful material, but should never be directly applied to a wounded surface. It is never aseptic, and will of necessity infect any wound with which it is brought in contact. Adhesive plaster is used to retain dressings, to keep bandages from slipping, to make compression, to immobilize a part, to make extension upon an extremity, or to protect a portion of the surface of the body. Resin-plaster has its sticky surface covered with tissue-

paper. When resin plaster is to be used, the tissue paper is removed and the plaster cut lengthwise into strips. The plaster is placed for a moment with the unspread side against a jug of hot water, and as soon as the spread side becomes sticky, it is ready for use. The part to which the plaster is to be applied, if hairy, should be shaved.

Rubber plaster will adhere most tenaciously without any previous heating, but it is more irritant to the skin than resin plaster.

Soap plaster does not adhere with sufficient tenacity to permit of its use as a material to make firm compression or extension. Its chief use is to cover and protect a part—for instance, an incipient bed-sore or a bony prominence—before splints are applied.

Strapping of the Testicle (Fig. 176).—This procedure is carried out

FIG. 176.—Strapping of the testicle (Smith).

in the subsiding stage of an epididymitis or orchitis, and is occasionally employed after tapping a hydrocele. Strips of resin plaster are employed, each strip being ½ inch wide and 10 or 12 inches long. After the scrotum has been washed, shaved, and dried, the surgeon constricts it at the upper end of the testicle, passes a circular strip of plaster around the scrotum above the testicle, and then applies a series of long recurrent strips, covering them with transverse strips.

FIG. 177.—Strapping of the breast.

Strapping of the Breast (Fig. 177).—In chronic inflammations of the breast, it is sometimes useful to strap with resin plaster. The material is cut in strips 2 inches wide and of sufficient length to pass under the breast, over the far shoulder, and across the back to the point of origin. The first strip is applied at the lower portion of the breast. The second strip is on a higher level and overlies one-third of the previous strip. In this manner the breast may be entirely covered.

Strapping of the Chest.—See chapter on Fractures.

Strapping of Ulcers.—See chapter on Ulcers.

Strapping of Joints.—See chapter on Sprains.

LOCAL APPLICATION OF HEAT.

Local heat is employed to treat inflammation, to allay pain, to arrest itching, to stop hemorrhage, to render joint-adhesions soft and elastic, to destroy infected areas or malignant growths. It may be applied as intermittent or continuous heat. The temperature employed varies with the method of application and the needs of the case. It may be so low as to irritate only slightly or so high as to cauterize the tissue. We would divide heat into two forms—solar and artificial. Solar heat is rarely used locally. To employ it, it is usually customary to concentrate the rays of the sun upon the diseased part with a convex glass. This method produces powerful counterirritation, and has been employed in the treatment of ulcers and skin-eruptions. Artificial heat is either dry or moist.

Dry Heat.—Dry heat may be applied locally by taking a plate of earthenware, a brick, a bag of salt, a piece of iron, or some other material, raising its temperature to the required degree, and placing it upon the part. If the material used is raised to a high temperature, it is customary to wrap it with a blanket or a piece of flannel before placing it upon the surface of the body. Ironing the part with a very warm iron is useful in muscular rheumatism. A cloth is laid upon the surface of the body, and the iron, as hot as can be borne, is passed up and down over the cloth. The hot-salt bag is a useful means of applying heat to the perineum. Heat may be developed locally by friction with the hands.

Mayor's hammer is occasionally used to apply heat locally. The hammer is dipped in very hot water, dried, and touched again and again to the surface of the body. This process is known as firing. The hot-water bag is the most generally employed means of utilizing local heat. The bag is filled with hot water, and after the cap is screwed down, it is carefully examined to see that it does not leak. It is then wrapped in a piece of blanket and laid upon the part. It is customary to apply heat in this manner in the treatment of shock, and great care must be taken not to burn the patient.

Leiter's apparatus contains many different tubes suitable for various parts of the body. These tubes are placed on the part, and hot water is made to flow through them. Dry hot air is very useful in chronic joint-inflammations. A special apparatus is made for the purpose of heating the air. This apparatus consists of a copper cylinder, which contains perforations to afford ventilation, and has an asbestos inner case. One end of the cylinder is closed, and the other end is fitted with a cover of thick material, which contains a central opening surrounded by a drawing-string. The affected extremity is wrapped in cotton and is placed in the apparatus, where it rests upon some dry absorbent cotton, as a hammock, the drawing-string is tightened, and the temperature is raised to 250° or 300° F.

Dry hot air has been used by Hollander for the cauterization of lupus. In order to accomplish this he drives air through a red-hot metal tube at a temperature of 300° C., and directs the air upon the part.

The Actual Cautery.—In order to cauterize the tissues, a metallic substance so hot that it destroys is applied to the part. The actual

cautery is extremely rapid in action, and is not so very painful if used at a high heat. The most convenient means of applying it is by the apparatus of Paquelin. In this apparatus the vapor of benzol is forced through the heated tip of spongioplatinum. The apparatus is prepared for use by fitting the rubber tube attached to the cautery end to one of the outlets of the benzol bottle, and fastening to the other outlet the rubber apparatus for driving air through. The tip is heated to a red heat in a spirit-lamp, the vapor of benzol is forced through by squeezing the bulb, and the metal can be kept at a red heat for an indefinite period. Cautery irons can be used instead of the instrument of Paquelin. We may use special irons or an ordinary poker, or, in some cases, a heated steel needle. Irons are made of various shapes and are set in wooden handles. They are heated in a charcoal fire or an ordinary range, and may be used white hot, red hot, or cherry red, according to the necessities of the case. If we wish to destroy tissue, the iron is used red hot; if we use to counterirritate strongly, it is white hot; if we wish to arrest bleeding, it is cherry red. In counterirritating a part with a hot iron, the instrument touches the skin here and there, or is drawn lightly over it in lines. We should not counterirritate with a hot iron over a bony prominence, an important nerve, or a large blood-vessel. When the cautery is used to arrest hemorrhage, firm pressure is made upon the part with a piece of gauze, the gauze is quickly removed, and the cautery is rapidly smeared upon the surface. The part is pressed upon lightly with a gauze sponge, and, if blood still oozes, the cautery is again applied. The cautery will arrest primary hemorrhage, but, unfortunately, in many instances when the slough separates, secondary hemorrhage will arise. If we wish to use the cautery in one of the body-cavities or -canals, it is best used as a galvanocautery, because an electrode can be introduced while cold, and after it has reached the region upon which we desire to operate, it can be instantly heated. The galvanocautery snare is a useful instrument with which to remove tumors from the nasal passages. To employ the galvanocautery an ordinary electric battery will not be sufficient. We must use a cautery battery—that is, a battery which contains large plates very near together. A cautery battery will keep the electrode constantly at a white heat. Electrodes for the application of the galvanocautery are made of various shapes and sizes.

Moist Heat.—Moist heat may be applied as a local hot pack. In applying this, the patient is wrapped in a dry blanket, a piece of blanket is wrung out of very hot water with the clothes-wringer, the blanket with which the patient is surrounded is raised, the hot piece applied to the seat of trouble and the patient again wrapped up with the dry blanket. Moist heat may be applied by sponging with hot water. This may allay pain and arrest itching. Soft sponges are soaked in water, hot water squeezed out upon the part, and the sponge is held for a minute or two in contact with the part until it begins to cool, when it is again filled with water and reapplied as before. Immersion of the extremity in hot water is especially useful in sprains of a joint. The extremity is placed in a bucket of hot water, and small quantities of very hot water are from time to time poured into the bucket from a tea-kettle. This gradual addition of hot water enables the extremity

to tolerate a considerable degree of heat. Compression with gauze pads soaked in hot sterile water or hot normal salt solution is used very constantly by the surgeon to arrest capillary hemorrhage. The plan is often invaluable. In order to carry it out with success, the water should be at a temperature of 115° to 120° F.

Heat and moisture are frequently applied to a part by means of a **poultice** or **cataplasm.** Many materials are used for the purpose of making poultices—flaxseed, bread and milk, potatoes, carrots, charcoal, etc.—but at the present time the old-fashioned poultice has so limited an application that it is unnecessary to dwell upon many of these forms. The poultice which is most frequently employed is made of ground flaxseed. A spoon and a tin basin are scalded. The flaxseed is put in a dry hot basin, and sufficient boiling water is added to make a thick paste. The material reaches the proper consistency when it is decided that the mass would stick if it were thrown against the wall. It is spread to the thickness of $\frac{1}{4}$ inch upon a piece of muslin, and is covered with cheese-cloth to prevent adhesion to the skin. When it is laid upon the part, it is covered with oiled silk or with wax paper. Such a poultice will retain its heat for five or six hours. Lint or spongiopilin soaked in hot water, laid upon the part, and covered with an impermeable material, makes an excellent poultice. The fermented poultice which was once extensively used for gangrenous processes was made by sprinkling yeast over an ordinary cataplasm. A charcoal poultice was made by stirring charcoal into the poultice mass. A sedative poultice contains 2 grains of opium to the ounce of poultice mass. A part must not be poulticed too long, especially in adynamic conditions, because vesication or pustulation may result; and a wound should never be poulticed except by antiseptic fomentations.

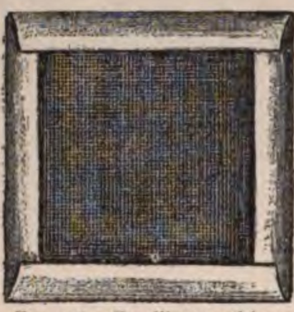

FIG. 178.—Emollient poultice.

Hot fomentations or **hot compresses** are used particularly to allay pain, to treat inflammation, and to restore the circulation of damaged areas. A hot fomentation is applied as follows: Flannel is folded into several thicknesses and is wrung out of water at a temperature of 120° F. It is then laid upon the part, covered with oiled silk or wax paper, and changed as soon as it begins to cool. It can be kept warm for hours by placing a hot-water bag upon the part over the flannel, such a dressing being, in reality, an excellent form of poultice. An antiseptic fomentation or an antiseptic poultice is used when it is necessary to apply heat and moisture to a wound, to an ulcer, or to a gangrenous process. An antiseptic fomentation is made by soaking a piece of sterile gauze in a hot solution of corrosive sublimate (1 : 1000), wringing it out, placing it upon the part, covering it with oiled silk, and laying outside of it a hot-water bag.

Steam has been used locally by some practitioners. Kahn has employed it in puerperal endometritis. He attaches a hose by one end to a kettle, by the other to a uterine applicator which has a hollow stem. The kettle is furnished with a thermometer and a

spirit-lamp. The steam is used for two minutes at 100° C., and then for one minute at 115° C., and it causes but little pain. For several days after it has been used intra-uterine douches are given. Steam has also been used for the purpose of disinfecting bone-cavities, and boiling oil and boiling water have been employed with the same end in view. These agents, unfortunately, invariably cause superficial necrosis.

Counterirritants.—Irritation of the surface of the body may be used for the purpose of benefiting internal derangements. We must be very cautious in using counterirritants if a person is lethargic, stuporous, or comatose, because in this condition we may do great injury, the individual feeling no pain, and being unable to call our attention to the destruction which is going on. Counterirritants should not be applied to paralyzed parts. Counterirritants are divided into rubefacients, agents which cause heat and redness; epispastics, agents which cause inflammation and vesication; and cauterants, agents which immediately destroy the tissues. The most commonly used rubefacient is ground mustard. The hot mustard foot-bath, which is a useful domestic remedy, is made by adding two tablespoonfuls of ground mustard to a basin of warm water; and in this mixture the patient places his feet. The water must be below 100° F., because hot water will destroy the ferment myrosin, and, as a consequence, the volatile oil of mustard, which is the rubefacient element, will not be formed. Mustard is generally used in the form known as a *mustard plaster*. To make a mustard plaster for an adult, take equal parts of ground mustard and of flaxseed meal and make them into a thick paste with tepid water. The mixture is spread on old muslin, is covered with cheese-cloth, is laid upon the part, and kept on from fifteen to thirty minutes. Occasionally mustard will form vesicles, and if such an accident happens, the vesicated area should be dressed with cosmolin or zinc ointment. In order to make a mustard plaster for a child, 1 part of mustard is added to 3 parts of flaxseed meal. The ready-prepared mustard plasters of the shops are known as mustard papers. They are decidedly strong. In order to prepare one for use, it should be dipped into tepid water, the mustard side covered with a piece of cheese-cloth, and the plaster laid upon the part.

Counterirritation can be effected by hot fomentations or the use of Mayor's hammer, to which allusion has already been made. Spirit of turpentine is a useful agent with which to counterirritate. It may be rubbed upon the part in its pure condition or may be mixed with an equal part of olive oil. The turpentine stupe is very useful. It is prepared as follows: Take a flannel cloth, fold it in several layers, wring it out in hot water, sprinkle upon it 5 to 10 drops of spirit of turpentine, lay it upon the part, and bind it on with a bandage. Instead of flannel, spongiopilin may be used.

The spice bag is a very common domestic means of obtaining counterirritation. It is a mild rubefacient, and can be kept on a part for many hours. It is made by mixing equal parts of nutmegs, cloves, cinnamon, and allspice, and half of a part of black pepper. This mixture is sewed up in a flat bag of old linen. The bag is quilted to prevent sagging of the contents. One side of the bag is wet with vinegar, warm brandy, or whiskey, and is laid upon the part. Counterirritation may also be effected by touching the part lightly with the cautery, by friction with stimulating liniments—for instance, camphor

liniment, soap liniment, or turpentine liniment; or by the use of capsicum plaster, Burgundy-pitch plaster, Canada-pitch plaster, or arnica plaster. Epispastics are used, particularly in chronic pleuritic effusion, in chronic inflammation of joints, and in inflammation of tendon-sheaths and bursæ.

Before blistering a part, it should be washed and dried; if it is hairy, it should be shaved. The favorite material for blistering is cantharides, which may be used in the form of the cerate, the cantharides paper, or cantharidal collodion. If we use the cerate, it should be spread on the center of a piece of adhesive plaster, free margins of adhesive plaster being left to adhere to the surface of the body. If a very prompt effect is desired, just before the blistering material is applied, the skin should be rubbed for a minute or two with spirit of turpentine. Blisters form on children more easily than upon adults, and in children it is wise to interpose a piece of thin tissue paper between the cerate of cantharides and the skin. In the adult, the blistering material is left in place for six hours and is then removed, and, if the blister is not found thoroughly developed, the part is poulticed for some hours. If the patient resents the pain, is very nervous, or in a debilitated condition, the blistering material is removed in two hours, and a flaxseed poultice applied. When the blister is fully developed, it is punctured at its most dependent portion to permit of drainage, and is dressed with cosmolin or ointment of oxid of zinc. If we wish to keep the blister open, the stratum corneum is cut away, and the blister is dressed with an irritant application, such as 5 drops of nitric acid to the ounce of cosmolin. If cantharidal collodion is used to make a blister, several layers of it are painted upon a part by means of a camel's-hair brush. If cantharidal paper is employed, it is cut to the proper size, greased with olive oil, laid upon the part, and held in position by rubber adhesive plaster. Blisters can be formed rapidly by the use of stronger ammonia. If a few drops are poured into a watch-crystal, and the crystal is laid upon the surface, a blister will form in fifteen minutes. A piece of lint can be saturated with ammonia, and, after being laid upon the surface, covered with oiled silk. Equal parts of ammonia and lard will blister in five minutes. Chloroform will rapidly blister. It is applied by moistening lint with the chloroform, placing the lint on the part, and covering it with oiled silk or a watch-glass. If a solid stick of silver nitrate is drawn across a part, it will vesicate. Tartar emetic ointment may be used for the same purpose. The hot iron at a white heat, brought near to the surface, will instantly vesicate. After this has been used, the vesicated area is dressed with iced water for an hour, and is then poulticed. The older surgeons used to employ Vienna paste. This consists of 5 parts of caustic potash and 6 parts of lime, made into a paste with alcohol. It will blister in five minutes; when it has made a blister, it is washed off with vinegar.

LOCAL APPLICATION OF COLD.

Cold is used to contract the vessels in inflammation, to arrest swelling, to allay pain, and to stop hemorrhage. It may be used as inter-

mittent or continuous cold, and also in the form of wet cold or of dry cold.

Wet cold can be used in the form of continuous irrigation. In order to apply irrigation, the part should be wrapped in wet linen and laid on a rubber sheet folded into a trough, the end of the trough emptying into a bucket. A vessel filled with cold water is placed on a shelf which is on a higher level than the bed. A wet lamp-wick can be carried from the reservoir to the part. The part will be kept wet because capillary attraction and gravity lead water from the reservoir. Evaporation greatly lowers the temperature. Instead of a lamp-wick, a rubber tube may be used to carry the fluid, a clamp being set upon the tube to regulate the amount of flow. The fluid used may be ordinary water, spring water, or iced water. If the water be too warm, it can be reduced to a temperature of 45° F. by the addition of 1 part of alcohol to 4 parts of water. Great cold can be obtained by the use of a mixture of 5 parts of potassium nitrate, 5 parts of ammonium chlorid, and 16 parts of water. If wet cold is used upon an open wound, the wound and the adjacent skin must be thoroughly asepticized and covered with gauze which is wet in an antiseptic solution; the fluid itself must be antiseptic, or at least sterile. Compresses soaked in iced water and frequently changed are very useful in the treatment of conjunctivitis and epididymitis.

Dry cold is usually employed in the form of an ice-bag. A rubber bag or a bladder is filled with finely cracked or ground ice. The bag is not laid directly upon the part, because it invariably becomes moist; a piece of flannel is always interposed between the bag and the skin. The part may be encircled with a rubber tube through which cold water flows; or Leiter's tubes may be employed, or pieces of metal, which have been chilled by soaking in a cold fluid, may be laid upon the diseased area.

ANESTHETICS IN MINOR SURGERY.

In minor operations it may be necessary or convenient to administer ether or chloroform exactly as is done in a major operation. In some cases a general anesthetic other than ether or chloroform is employed, and in many cases only local anesthesia is necessary. If ether or chloroform is used, the same care is taken and the same precautions are observed as in a major operation. The fact that the operation is trivial does not mean that an anesthetic has slighter dangers than usual. Many of the accidents which have occurred during anesthesia have arisen during the performance of small operations. The temptation in such cases is to operate before the reflexes are abolished; and, when the reflexes are not abolished, a violent peripheral irritation may produce cardiac or respiratory inhibition, and such an accident is most apt to occur when an operation involves the trajectory of the fifth nerve. In truth, incomplete anesthesia is a condition of greater danger than is complete anesthesia.

Ethyl Bromid.—Ethyl bromid very rapidly produces anesthesia, and, after the administration is suspended, consciousness is quickly regained. The drug should be kept in a tightly stoppered yellow glass bottle. A child can be given 3 drams, and an adult 6 drams.[1]

[1] Cumston, *Boston Med. and Surg. Jour.*, July 20, 1894.

In administering ethyl bromid, the entire amount to be given is poured on a folded towel or an Esmarch mask, and the mask or towel held closely to the mouth and nose, so as to exclude air. Unconsciousness can be produced in from half a minute to two minutes. The moment the patient becomes unconscious, the inhaler is removed, and the operation is proceeded with. It will be unsafe to give more of the anesthetic, because the administration of a larger amount of ethyl bromid will produce muscular contractures, rigidity of the jaw, and irregularity of respiration. After the withdrawal of the inhaler, the patient will remain unconscious for about three minutes, and will then promptly return to consciousness (Cumston).

There are very rarely any disagreeable after-effects. The safety of this drug has been a matter of some question. Sudden death has happened from its use. Cumston has used it in 200 cases, and believes it to be absolutely safe; but he says that serious lesions of the kidneys, lungs, or heart are contra-indications to its use. Lauder Brunton does not consider the drug absolutely safe. The author has knowledge of 1 death produced by it.

Nitrous Oxid.—Many minor operations can be performed when the patient is under the influence of nitrous oxid. This agent can be given alone or combined with oxygen gas. The administration of nitrous oxid requires a rather bulky and expensive apparatus, and the gas is not readily applied in private houses; so that, if it is desired to use it, the patient is usually taken to a hospital or to a dentist's office. An impediment to the extensive use of nitrous-oxid gas has always been the brevity of the anesthetic state which it induces and the danger of prolonging the anesthesia by continuous administration. Paul Bert some time since discovered that if nitrous oxid were mixed with oxygen, and an animal were placed in a chamber in which pressure was increased, anesthesia could be kept up indefinitely with safety. Since then it has been made evident that it is not necessary to increase atmospheric pressure, and that a mixture of equal parts of the gas and of oxygen can be continuously inhaled and will produce prolonged anesthesia (Hewitt's apparatus). If oxygen and nitrous oxid are so given, there will be from thirty to forty seconds of available anesthesia after the removal of the face-mask; but with this mixture anesthesia can be maintained while an operative procedure of some length is being carried on. Ordinarily, nitrous oxid is not to be used as an anesthetic in the reduction of a dislocation, the setting of a fracture, the examination of a joint, or the stretching of the sphincter, because it causes muscular rigidity; but nitrous oxid mixed with oxygen does not produce rigidity.

Primary Anesthesia.—Where ether is rapidly inhaled, there arises in many cases a temporary condition, in the early period of the administration, in which the patient is confused, but not unconscious, and yet has no appreciation of pain. This stage is known as primary anesthesia. It lasts about thirty seconds, and during its continuance a simple operation, like the opening of an abscess, may be performed without pain. In order to induce primary anesthesia the patient should be recumbent, with one arm raised vertically. He should count out loud. An Allis inhaler is placed over the mouth and nose, and ether is poured on steadily. In a little time the counting becomes irregular and confused, or is stopped entirely; the arm drops to the side, and the time has come for operating.

Local Anesthesia.—Local anesthesia can be induced by cold. Cold may be brought to bear upon a part by the use of ice and salt (Arnott's plan), the injection of iced water, spraying the part with ether (Benjamin Ward Richardson), with rhigolene (Bigelow), or with ethyl chlorid. If ice is used, it is to be broken up very fine, and 1 part of

salt is mixed with 2 parts of ice. The mixture is wrapped up in a piece of cheese-cloth and laid upon the part. In about fifteen or twenty minutes the skin blanches, and the part is ready for operation. The spray of ethyl chlorid is the most rapid and convenient means of freezing. The drug is furnished in a glass tube with a narrow neck, which is kept closed with a brass screw-piece (Bengué's apparatus). When a part is to be frozen, the brass cap is removed, and the tube is held in the palm of the hand, so as to warm it. A fine spray of ethyl chlorid is projected through a small opening in the neck of the bulb and thrown upon the surface to be frozen. The tube should be held 8 to 10 inches from the skin of the patient. As the skin freezes, it suddenly whitens; it will remain anesthetic for several minutes. Freezing of the part, no matter how it is brought about, is in most instances not thoroughly satisfactory. Of necessity, a larger area is frozen than requires to be cut. The freezing makes the tissues hard and difficult to divide, and alters very much their appearance. The process of freezing is itself painful, and, occasionally, sloughing follows the procedure.

Freezing is satisfactory only when we wish to make a small incision or a puncture—for instance, opening an abscess, tapping a hydrocele, or penetrating the skin with a needle to introduce Schleich's fluid. Local anesthesia can be obtained to a certain extent by the use of electricity. This has been particularly employed in dentistry. In some cases needles are introduced into the tissues and the current is passed. In other cases, the electric current is used to carry cocain into the tissues (electrical cataphoresis). Local anesthesia may be induced by the local application of certain drugs. In some cases, the agent is applied to the surface; in others, it is injected into the tissues.

Cocain.—Cocain is a very useful agent. It will anesthetize mucous membranes if applied to the surface, but to affect the skin and deeper structures the drug must be injected. It is instilled into the conjunctival sac, injected into the urethra and bladder, painted upon the larynx, and sprayed into the nares. In the vast majority of cases the use of cocain is productive of no harm. In many cases it produces slight toxic symptoms. In some cases grave symptoms follow its use, and in a few reported cases it has produced death (see chapter on *Anesthetics*). Injection about the head is more dangerous than in other regions (Wolfler). A warm solution is more efficient than a cold solution, and as less of it will produce anesthesia, it is the safer. Because of the dangers which possibly reside in cocain, it should be administered while the individual is recumbent, and at the first sign of trouble, active treatment should be instituted (see chapter on *Anesthetics*). In anesthetizing the eye, the strength of the solution of cocain varies from 1 to 4 per cent., according to the depth and duration of anesthesia required. If a foreign body is to be removed from the surface, a 1 per cent. solution is used. If a cataract is to be extracted, a 4 per cent. solution is employed. A drop or so of the fluid is instilled every ten minutes, until three instillations have been made; the parts will then be entirely insensitive. In the nose, pharynx, larynx, and tonsils, the strength of the solution varies from 2 to 20 per cent. A strong solution is far safer when used in the larynx than in the pharynx or esophagus. Over $\frac{1}{8}$ grain must not be injected under the mucous mem-

brane of the mouth (Stoerk). Over ¾ grain should not be applied to a mucous surface. In the urethra a 4 per cent. solution is injected; in the bladder a 2 per cent. solution is used. For the vulva, vagina, and uterus a 5 per cent. solution is employed; for the rectum a 5 per cent. solution is employed, pieces of cotton being saturated with the drug and introduced into the rectum. To secure insensibility of the skin, cocain must be injected with a hypodermic syringe. The solution should be of the strength of 1 or 2 per cent., and it is desirable to have it warm. More than ½ grain should never be injected, especially about the face and genitals. The surgeon should be careful not to throw the drug into a vein. The injection is made into the skin, but not into the subcutaneous areolar tissue. Injection into the subcutaneous tissue is both dangerous and unsatisfactory.

Method of Injection.—If the region is suitable, a rubber band should be applied above the seat of operation. A sharp needle is placed at an angle of 45° to the surface and pushed through the epiderm and into, but not through, the Malpighian layer. A minim or so of the solution is forced out of the syringe. A whitened elevation will be formed. The needle is withdrawn, and at the margin of the whitened area and in the direction in which the incision is to be made, the needle is inserted again and another minim or so forced out. When the area which is to be operated on has been injected, the surgeon waits five minutes and then proceeds with the operation. After the skin has been divided, if it is necessary to cut the subcutaneous tissues, a few drops of a 1 per cent. solution of cocain are poured into the wound from time to time. After the completion of the operation, the constricting band is loosened for several seconds and readjusted for several minutes. Again it is loosened and readjusted, and so on three or four times (Wyeth). In this way but a small quantity of cocain is taken into the system at one time, the organism is able to distribute it and dispose of it, and no toxic symptoms arise. Corning demonstrated that if the [illegible] is arrested, the action of cocain can be very greatly prolonged. His method is as follows: A piece of elastic webbing is [illegible] around the limb above the field of operation [illegible] with a [illegible] the webbing [illegible] from the periphery to the [illegible] margin of the field of operation [illegible] rubber band applied [illegible] of the field of operation. The [illegible] this method [illegible]

[illegible]

ing a drug over both supra-orbital notches. Injection over the ulnar nerve causes anesthesia of the entire nerve-distribution. This plan has been used extensively in the clinic at Helsingfors, and over 200 operations have been performed (amputation of the finger, the toe, circumcision, etc.).

Schleich's Infiltration Anesthesia.—Schleich was impressed with the facts that not only is cocain sometimes dangerous, but it is often unsatisfactory, because it is not diffused widely enough to anesthetize anastomosing nerve-fibers. It was long ago pointed out by Leibreich that an injection of water produces anesthesia, but also causes pain (painful anesthesia). Schleich found that injection of normal salt solution produces no pain and causes no anesthesia; but if 0.2 of a 1 per cent. solution is injected no pain is produced, but the part, if uninflamed, becomes distinctly anesthetic. In order to obtain anesthesia from salt solution, the area must be infiltrated and distended. This anesthesia is due to pressure and to slight irritation of the nerves. Schleich found, further, that if minute quantities of cocain, carbolic acid, and morphin are added to the salt solution, the anesthetic effect is greatly intensified and prolonged, and can be distinctly obtained even in inflamed tissues.

The reason that such dilute solutions of these drugs have a distinct anesthetic influence is because the process of infiltration brings the fluid into direct contact with all the nerve-filaments of a considerable area. Schleich uses one of three solutions, all of which are sterile, should be recently made, and should be cooled on ice just before using.

Solution No. 1 is the strong solution, and is used for operations upon inflamed and hyperesthetic areas. It is composed of—

℞	Cocain. mur.,	.20;
	Morph. mur.,	.025;
	Sodii chlor.,	.20;
	Aq. dest.,	ad 100.00.

Sterilize solution, and add gtt. ij of 5 per cent. carbolic acid.

Solution No. 2 is the one commonly employed. This consists of—

℞	Cocain. mur.,	.10;
	Morph. mur.,	.025;
	Sodii chlor.,	.20;
	Aq. dest.,	ad 100.00.

Sterilize, and add carbolic acid as above directed.

The third solution is mild and employed for slight operations upon nearly normal tissues. It consists of—

℞	Cocain. mur.,	.01;
	Morph. mur.,	.005;
	Sodii chlor.,	.20;
	Aq. dest.,	100.00.

Sterilize, and add carbolic acid as above directed.

Method.—An ordinary aseptic hypodermic syringe is employed. It is well to freeze with ethyl chlorid the point of skin where the needle

is to be first inserted. In dealing with a mucous membrane, instead of freezing it should be touched with pure carbolic acid, or with a little cocain. If the tissues are inflamed, the first injection should be made in sound tissue, and the subsequent ones in inflamed tissue. The needle is inserted obliquely, and its entire length is carried into the Malpighian layer (Fig. 180); a few drops are forced out, and a white

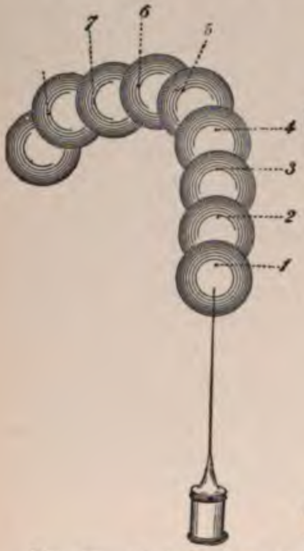

FIG. 179.—Showing how the successive wheals are raised, the point of the syringe being inserted at the points marked by the dots (Van Hook).

FIG. 180.—The syringe-point stops at the papillary layer, and the fluid lodges in the skin itself (Van Hook).

FIG. 181.—Showing mode of injecting the fluid under an abscess (Van Hook).

wheal, looking like a mosquito bite, is formed (Van Hook). The area occupied by the wheal becomes at once anesthetic. At the margin of the wheal the needle is reinserted, more fluid is forced out, and the process is carried on in this way until the required area is infiltrated (Fig. 179). The skin will remain anesthetic for at least twenty minutes. If other structures besides the skin require to be anesthetized, the needle is pushed into the deeper tissues and they are infiltrated. Lund says that the infiltration should be around and underneath the tissues, so as to encompass them with artificial edema. Fascia, muscles, and periosteum can be anesthetized as well as the skin (Van Hook). When the anesthesia is complete, the skin is incised and the operation is proceeded with. If a nerve-trunk is exposed, it should be touched with pure carbolic acid (Schleich). There will be very little bleeding, but if it becomes necessary to clamp a vessel before applying the forceps, it should be touched with pure carbolic acid. Injections can be made into an abscess-wall, but are never made into an abscess-cavity, the sac of a cyst, or the tissue of a tumor (Lund). Tissues which have been subjected to infiltration seem to have their vital resistance lessened, and are more liable to infection than are non-infiltrated tissues.

Eucain.—Eucain is used in the same manner as cocain, and is

extensively employed as a substitute for the latter. It has great advantages. It is decidedly safer than cocain; a solution of it can be rendered sterile by boiling, without altering the composition of the drug, and it produces complete insensibility. When used in the eye it produces considerable smarting and burning, and when used in the urethra and bladder may lead to inflammation. In a certain number of cases, injection into the tissues causes persistent sloughing. This is particularly true in fatty tissue, in the matrix of the nails, in bursæ, and in tendon-sheaths. This tendency to cause sloughing in some cases is the only objection to its employment, and is apparently the only reason why it does not completely displace cocain.

LOCAL BLOOD-LETTING.

Bleeding may be practised for its local effect; it is then known as local bleeding or depletion. It may be employed for its constitutional effect, and it is then known as phlebotomy or venesection. Local bleeding may be carried out by puncture, by scarification, by leeching, or by cupping. In puncturation or puncture many punctures are made through the skin, and they are not carried deeper than the subcutaneous tissue. The punctures can be made by means of a tenotome, a needle, or a sharp-pointed bistoury. When numerous punctures are made, the procedure is often spoken of as multiple puncture. Puncture is not only useful in abstracting blood locally, but it also relieves tension in regions of inflammation. By scarification or incision we mean the making of many small incisions. These cuts may be deep, but, as a rule, they are not carried entirely through the skin. After scarification, the application of warm aseptic fomentations will maintain the flow of blood and serum.

Leeches are not used as frequently as in former days. Regions which contain large amounts of loose cellular tissue should not be leeched. Such regions are the prepuce, the labia majora, the scrotum, and the eyelids. It is not wise to leech the face, because of the permanent scar which will result; nor should leeching be carried out near specific ulcers or inflammations, or near a superficial artery, vein, or nerve. A leech is never applied over the focus of inflammation, but is placed between the inflammation and heart, or at the periphery of the inflammation. In epididymitis the leeches are applied over the spermatic cord, and in ocular inflammation, to the temple. Before applying a leech, the part should be washed, and shaved if it is hairy. If the leech refuses to take hold, smear the part with milk or with a little blood. Place the leech upon the surface under a glass tube or an inverted wine-glass. A leech should not be pulled off, but should be permitted to drop off, and it can be caused to drop off at any time by sprinkling it with salt. After the leech has dropped off, if we desire the bleeding to continue for some time, apply warm aseptic fomentations. If bleeding persists inordinately, it may be arrested by the use of styptic cotton and pressure. A Swedish leech will draw from 4 to 6 drams of blood, the American leech only about one-half this quantity. Heurteloup's artificial leech is in reality a wet cup.

Dry Cupping.—A dry cup brings about local depletion by draw-

ing blood from the depths to the surface of the body. Of course, by the use of a dry cup no blood is actually abstracted. A cupping-glass is a small glass which has at its top a valve and a stopcock. Such a glass is placed upon the skin, an air-pump is fastened to it, and as the air is exhausted the skin bulges into the cup. When the air has been exhausted to the required degree, the stopcock is closed and the air-pump is withdrawn, the cup being left in place for a few minutes. When we desire to remove the cup, the stopcock is opened, and the air immediately enters. Cupping can be done in an emergency by taking a tumbler, placing in it a piece of paper soaked with alcohol, lighting this paper, and inverting the glass rapidly and placing it upon the skin. In order to remove such a glass, press the finger beneath the edge of the glass and raise it from the skin, so that the air will enter.

Wet Cupping.—Before applying wet cups the skin should be sterilized. A dry cup is applied to draw a considerable amount of blood to a part; the cup is removed, and the skin is cut by touching the spring of a scarificator—an instrument that contains numerous blades, which fly out when the spring is loosened. After the employment of the scarificator, the cup is again applied, and is retained in place as long as the blood continues to flow. Instead of applying the scarificator, a few incisions may be made through the skin by means of a scalpel.

Phlebotomy or Venesection.—The instruments which are necessary for this operation are a lancet or bistoury, a fillet or tape, an antiseptic pad, and a bandage. The patient sits in a chair, with the arm abducted, extended, and inclined a little outward. The surgeon stands to the right of the arm, the parts are thoroughly asepticized, and the tape is tied around the arm in order to make the veins prominent (Fig. 182). Some surgeons cause the patient to grasp a stick firmly and work the fingers, in order to make the veins swell. The puncture can be made in either the median cephalic or median basilic vein, the median basilic being the one usually selected (Fig. 183).

FIG. 182.—Incisions for venesection (Bernard and Heuette).

FIG. 183.—Superficial veins in front of elbow (Bernard and Heuette).

The operator must be careful not to cut completely through the vein, because the brachial artery is directly beneath it. The surgeon steadies the vein with the thumb and divides it two-thirds through by an oblique cut. The thumb is removed and bleeding goes on. When the patient

becomes faint, the fillet is removed, a pad of antiseptic gauze is placed over the puncture, and a spiral reversed bandage of the hand and forearm and a figure-of-8 of the elbow are applied. The arm is placed in a sling and carried there for several days. If the individual is extremely fat, or is a child in whom the veins in front of the elbow cannot be easily found, venesection may be practised on the external jugular vein. Sometimes bleeding may be carried out by opening the internal saphenous vein.

Intravenous Injection of Saline Fluid.—Injections of saline fluid are extremely useful in the treatment of shock, hemorrhage, sepsis, and suppression of the urine. The best instrument to employ is Colin's apparatus (Fig. 184). This consists of a bell-shaped metal reservoir which has a syringe attached to it. To the end of the syringe is fastened a rubber tube, which terminates in a metal cannula. Between the reservoir and the syringe is a ball valve, which renders the passage of air impossible. When the reservoir is filled with fluid, every time the piston of the syringe is pulled out, $\frac{1}{2}$ ounce of the fluid passes into the barrel of the syringe; and every time the piston is pushed in $\frac{1}{2}$ ounce of fluid is projected from the cannula. Before using this instrument it should be carefully sterilized. If Colin's apparatus is not at hand, a glass funnel attached by a rubber tube to an aspirating trocar will make a very satisfactory instrument. As a rule, the injection is made into the median basilic vein, but if the patient is much collapsed and the veins are small, the basilic itself is chosen. A tape is tied around the arm above the elbow to make the veins prominent. The surface is sterilized, an incision is made over the line of the vein, and the vessel is exposed to the extent of about an inch or more. A catgut ligature is passed around the lower end of the exposed portion of the vein and tied. A small transverse incision is made in the middle of the exposed portion of the vein, and the cannula, filled with fluid, is introduced in the direction of the heart. A catgut ligature is passed around the portion of the vein carrying the cannula, and one knot is tied. This second ligature brings the vein-walls into close contact with the cannula and prevents leaking (Fig. 184). The saline fluid is slowly introduced. When a sufficient amount has been given, the cannula is removed, the second ligature is tied, the skin-incision is closed with sutures, and an aseptic dressing is applied to the part.

FIG. 184.—Intravenous injection of saline fluid (Da Costa).

Hypodermoclysis. — Hypodermoclysis is the introduction of saline fluid into the subcutaneous cellular tissue. The fluid can be

introduced by means of a fountain syringe and an aspirating trocar and cannula. After the skin has been sterilized, the trocar is plunged into the subcutaneous tissue of the loin, buttock, scapular region, or submammary region. The trocar is withdrawn, the cannula being left in place. A fountain syringe has been previously filled with hot sterile salt solution; the tube of this syringe is attached to the trocar, and the reservoir is hung several feet above the level of the bed. The fluid runs in slowly, and absorption will be greatly facilitated by occasionally rubbing the infiltrated area. After about a pint has been introduced, the cannula is removed, and the small puncture in the skin is covered with collodion. If the condition of the patient is such that more than a pint must be given, the operation is repeated in another region.

Intramuscular Injections.—These injections may be used in cases of paralysis, strychnin being the drug which is usually employed. The limb is placed in a position to make the muscle tense, the needle is pushed directly into the thickness of the muscle, and the fluid is slowly introduced.

Injections of Mercury for Syphilis.—Injections may be made into the subcutaneous tissue of the loins, buttocks, or scapular regions (see *Syphilis*). Injections may also be made into the veins (Bacelli, J. Ernest Lane, Abadie, and Lewin). The solution used is a 1 per cent. solution of cyanid of mercury, 20 minims being injected every day or every other day. A tape is applied around the arm to make the veins in front of the elbow prominent. The surface is sterilized, and the needle is inserted into the most prominent vein and toward the heart. The bandage is removed, the fluid is slowly injected, and the hypodermic needle is withdrawn. Digital pressure is made over the puncture for a few seconds.

Stomach-tube.—The stomach-tube is employed to empty the stomach of poisonous material, to obtain the secretions of the stomach for testing, to introduce food, or to wash out the stomach (lavage or irrigation).

The ordinary stomach-tube is made of red rubber, and is about 30 inches long and $\frac{3}{8}$ inch in diameter. It is introduced while the patient is sitting with his body erect and his head thrown back. The tube is warmed and anointed with glycerin. The surgeon stands in front of the patient, introduces his left forefinger and the tube into the mouth, and carries the tube to the back of the pharynx while the finger directs it over the epiglottis. From the back of the pharynx it is carried gently into the stomach, the patient facilitating its passage by making attempts to swallow.

If we desire to give food through the tube, as must sometimes be done in cases of profound melancholia, after the instrument has been passed into the stomach, a funnel is placed in the free end of the tube and liquid food poured slowly into the funnel. For the purpose of feeding an insane person it is usually preferable, however, to carry a small tube along the floor of the nares and into the pharynx, and pour

the liquid food into a funnel which is attached to the free end of the tube.

In order to wash out the stomach (lavage or irrigation), the tube should be 60 inches long with a diameter of $\frac{1}{2}$ inch. One-third of the tube is introduced as directed above. Lukewarm water is poured in through the funnel, and is permitted to run out by siphonage; the process is repeated until the water runs out clear.

The washing should be practised before breakfast, when the stomach is empty, except in those cases in which there are much distention and misery at night, and then it should be employed at night, four hours after supper. If much mucus is present, a 1 per cent. solution of common salt or a 3 per cent. solution of sodium bicarbonate should be used instead of lukewarm water.

In cases of poisoning, the stomach should be washed out as above directed, and the antidote can be added to the fluid which is introduced. Some physicians, however, still prefer to employ the stomach-pump in poisoning cases.

In order to obtain the gastric juice for examination, the procedure is as follows: The secretion of gastric juice is stimulated by introducing food in the early morning, when the stomach is empty. The patient is given Ewald's test-breakfast, which consists of a dry roll and $\frac{3}{4}$ of a pint of tepid water or very weak tea. In one hour the stomach-tube is introduced. The stomach-tube used for this purpose has an opening in the end and two lateral openings. After the tube has been introduced, the contents of the stomach can be extracted by the use of a syringe or pump, by the expansion of a compressed elastic ball (Mallard), or by Ewald's "method of expression." In Ewald's method the surgeon makes abdominal pressure, or the patient tries to eject the fluid, and the stomach-contents are forced out of the tube.

The Rectal Tube.—This tube may be used to withdraw gas or to introduce fluids. The instrument should be made of soft rubber, and must be used very gently. A hard instrument may inflict great damage, and the forcible use of any instrument may be productive of harm. In order to introduce a rectal tube, the patient is placed upon his left side, and the tube is warmed and anointed with glycerin. The surgeon introduces the greased index finger of his left hand into the rectum, using it to direct the tube as it is being passed by means of the right hand. Occasionally, the tube catches in a mucous fold and bends upon itself. If doubling occurs, the tube should be withdrawn and introduced again.

If the surgeon desires to introduce fluid into the intestine, the projecting end of the tube is attached by means of a large piece of rubber tubing to a fountain syringe or a reservoir bottle, and fluid is allowed to run into the rectum by the influence of gravity.

In order to treat intussusception by inflation, the patient is anesthetized, a tube is inserted into the rectum, the outside of the tube around the anus being packed with cotton, which is held by an assistant. This tube is connected by means of a rubber tube with a pair of bellows. The child is inverted, and the bellows are worked slowly (T. Pickering Pick).

Intussusception may be treated by hydrostatic pressure. The patient is prepared as for inflation. A fountain syringe filled with warm normal salt solution is raised 3 feet above the bed after being attached by means of a long tube to the rectal tube. In an infant of less than one year of age, not over 1½ pints can be introduced with safety. The fluid is allowed to remain in the intestine for five or ten minutes and is then permitted to run out.

In order to give an enema, employ an ordinary fountain syringe. The nozzle should be introduced just within the sphincter. Great gentleness should be employed, because injury may be done to the rectum by a careless person. It is better not to employ a hard nozzle at all, the portion of the tube which enters the rectum being of soft rubber. Such a tube is introduced as directed above, and the fluid is permitted to flow in slowly. Glycerin can be injected by means of an ordinary syringe.

A nutritive enema can be injected into the rectum by means of an ordinary syringe, or thrown in by a fountain syringe. A nutritive enema should never be bulky; a considerable amount of fluid will be almost certainly expelled, and ℥ij is an amount which should not be exceeded.

CHAPTER XIV.

ANESTHETICS AND SURGICAL ANESTHESIA.

THE PHARMACOLOGY OF ANESTHETICS.

The differentiation of narcotics into anesthetics and hypnotics is based mainly on practical grounds, and is not a strict one. A substance may be used in one case to abolish the sensation of pain—that is, as an anesthetic, and may serve in another case to induce sleep, as a hypnotic.

Moreover, the anesthesia may be a general one, if produced by influence on the central nervous system, or only localized, if the peripheral sensory nerve-endings are directly acted upon. In the present chapter we shall consider only briefly the pharmacology of substances used in surgery to produce general insensibility. This surgical anesthesia is characterized by loss of consciousness, loss of sensibility, and muscular relaxation.

Quite a number of chemical substances or their mixtures have been tried for this purpose since surgical anesthesia was first practically demonstrated by Morton—now over fifty years ago. All the substances which have been employed to induce a more or less marked general anesthesia are volatile at ordinary temperatures. Their vapors, mixed with air, are inhaled, and in time produce in the subject experimented on the characteristic conditions which constitute surgical anesthesia. How are these effects produced? Many hypotheses have been brought forward to throw light upon this question, but the true causation of anesthesia still remains unknown.

From the first, anesthesia was thought to be produced by an indirect influence upon the central nervous system. Faure believed that narcosis was due to stimulation of the vagi, followed by cessation of the pulmonary circulation and coagulation of the blood in the pulmonic system. He believed that the chloroform did not enter at all into the blood. Dieulafoy, Krishaber, and Claude Bernard repudiated this theory. Snow believed that the peripheral sensory nerves were made insensible by chloroform, and that the central nervous system played no part in general anesthesia. Claude Bernard showed that the theory that narcosis was due to circulatory changes in the brain was incorrect. He proved that anemia of the brain was not the cause of narcosis, but only the sequel of it. Later, narcosis produced by chemical substances was thought to be due to an impairment of oxidation, and to be more or less identified with asphyxia. It was believed that through the influence of chloroform or other narcotics the normal oxidation-power of the red blood-corpuscles was interfered with by their partial destruction, and that narcosis was the result.

Boettcher has shown that chloroform dissolves red blood-corpuscles in the presence of atmospheric air, and Bonwetch noticed that oxyhemoglobin does not oxidize certain substances in the presence of chloroform, which otherwise would be oxidized. These observations have been made only upon blood outside the body, never while circulating in the system. If the red corpuscles were dissolved during narcotization, hemoglobinuria would inevitably be the sequel; but such changes in the urine do not take place. That the effect produced by anesthetics is not dependent upon changes in the red blood-corpuscles has been proven beyond doubt. Lewisson showed that a frog whose blood was replaced by salt solution can be narcotized quite as well as a normal frog, only the process takes a longer time. Animals without red blood are affected by anesthetics in the same way as

those that have red blood. Even plants may be anesthetized (Marcet). That anesthesia produced by narcotics is not caused by asphyxia was first shown by Claude Bernard. He showed that cerebral circulation was not the same in narcosis as in asphyxia. That respiration is also different in the two cases was demonstrated by Knoll. In recent years the same author, in collaboration with M. Pick, has even demonstrated that the type of returning respiration in resuscitation after ordinary asphyxia differs from that which follows stoppage of respiration in anesthesia.

Through the experimental researches of Claude Bernard, Flourens, Hitzig, Bernstein, and others, it has been proved, and is now generally accepted, that narcosis due to anesthetics is produced by a specific action of these substances on the central nervous system, and that the blood, or, in the case of plants, the circulatory nourishing fluid, acts only as the carrier of the anesthetic. How this specific action on the central nervous system is produced still remains a mystery.

Claude Bernard thought that the nerve-cells were reduced under the influence of narcotics to a state of "semi-coagulation;" Binz treated parts of the brain directly with narcotics, and noticed changes in the nerve-cells. These views are very interesting, but they have not enlightened us as to the real cause of the production of narcosis. Whether this will ever be done is doubtful, for the changes in the nerve-cells produced by anesthetics must be only temporary, or, if I may say so, functional, and not organic. Otherwise it would be impossible to understand how the normal functions of the central nervous system may be so quickly restored when the anesthetic is removed and uncontaminated air is inhaled. In short, we know only that general anesthesia is produced by the action of an anesthetic upon the central nervous system; the process itself is unknown. To produce general anesthesia, the narcotic must be taken up by the blood, or, in the case of plants, by the circulating fluid (Arloing). With animals, the only practical way is by inhalation. Intravenous injections, administration by the mouth, subcutaneous or intramuscular injections, or rectal administration (Abner Post and Bull) of the anesthetics all produce a varying amount of narcosis after the substance has been taken into the circulation; but none of these methods has any real advantage over inhalation. In most of them the local irritant action of the anesthetic is generally more marked, and besides, a proper regulation of the absorption is more difficult. The local irritant properties of all anesthetics must be strictly separated from their general effects. As a result of this local irritation, increased salivation and bronchial secretion are to be observed when an anesthetic is inhaled. Besides this local action, a reflex effect may be observed, especially in rabbits. As soon as such an animal inhales the first whiff of ether, respiration and circulation cease immediately, to begin again after a few seconds. This sudden cessation of respiration and circulation is due to reflex stimulation of the trigemini and the superior laryngei; it does not occur if both trigemini are cut, and is less marked when the laryngei are severed (F. Franck). This same sudden standstill of respiration and circulation is said to occur also in human beings, especially with ether, and the sudden death sometimes observed at the beginning of narcosis is thus explained. But this reflex effect produced by ether and some other narcotics is by no means a peculiar property of these substances, for other irritants, such as ammonia, produce the same phenomenon.

As soon as the anesthetics have passed the primary respiratory channels, they enter the lungs, are there absorbed by the blood, and by way of the left ventricle are distributed through the whole body. It is only then that the general or constitutional effect of the narcotic is produced. The laws governing the absorption of anesthetics from the lungs are of the utmost theoretical and practical importance. It is to Paul Bert that we owe most of our knowledge on this point. From his experiments he deduced the fundamental law that the absorption of the anesthetic and the proportion which is retained in the blood and system are dependent on purely physical facts, other things being equal in the condition of the subject narcotized. The intensity of action depends on the partial tension, or the volume per cent., of the anesthetic—that is, on the fixed quantity of the narcotic contained in the inspired air. From a certain mixture of an anesthetic the blood continues to absorb, until the partial tension of the anesthetic in the blood is equal to its partial tension in the air inhaled. If inhalation is continued, the blood, and therefore the subject under narcosis, cannot take up a greater proportion of the anesthetic than is contained in the air inspired. If a new mixture of air with a higher partial tension is now used, the blood will again absorb more of the narcotic, until equilibrium is re-established between the partial tension of the gas in the blood and the gas in the air of inspiration. Since only the quantity of a poison actually circulating in the system acts as poison, the intensity of action of an anesthetic will depend not only on the total quantity employed, but on its partial tension in the air inhaled. The quantity of an anesthetic used in a narcosis is therefore no real indicator of the condition of the subject during narcosis. A small quantity, if inhaled in concentrated form—that is, under a high partial tension—will act much more vigorously than a larger quantity more diluted with air. The law of partial tensions guides the study of the physiological effects of anesthetics and the determination of the best possible condition for producing anesthesia.

Thus, Spencer found that animals experimented on were not narcotized, even after two hours, if the inhaled air contained only 1.5 vol. per cent. ether; if the air contained 2.5 vol. per cent. ether, the resulting narcosis was still incomplete. With 3.19–3.62 vol. per cent. ether, complete narcosis was obtained in rabbits and cats in twenty-five minutes. Narcosis could be maintained for hours without any harmful influences upon respiration or circulation. Paul Bert, and recently Dreser, had already used such graduated mixtures of anesthetics and air to produce narcosis in human subjects with good results. M. Rosenfeld made similar experiments with chloroform upon rabbits. He found that in using chloroform of 0.96–1.01 vol. per cent., rabbits could be kept narcotized for hours without respiratory standstill. With higher percentages standstill occurred, and with lower percentages narcosis was incomplete.

Anesthetics are, as we have already stated, absorbed from the lungs by the blood, but they are not present simply in solution. At least, this is not the case with chloroform. Schmiedeberg supposed that the chloroform entered into a kind of combination with certain substances of the blood, and was thus transported into the different parts of the system. Pohl has recently demonstrated that the chloroform is loosely combined with the morphological elements of the blood. He found that during narcosis the red corpuscles contained more chloroform than the serum; but this combination of red corpuscles and chloroform

is a very loose one, for all the chloroform may be separated by a stream of air. The effects of all anesthetics upon the circulation are more or less marked. As is very well known, chloroform is a much more powerful depressant than ether. The effects upon the circulation are due to the direct action of the anesthetic, partly upon the heart and partly upon the vessels. The action upon the heart consists in a direct paralysis of the motor ganglia; as a sequel, the heart-beat will be less vigorous, and, if the paralysis is complete, the heart may come to a standstill even before respiration stops. Such a condition may be observed both in human beings and in the lower animals.

The direct influence upon the heart-muscle has been recently studied by Dieballa on the isolated frog's heart. He compared the quantitative actions of different narcotics, using these substances in their molecular proportions. He found in the main no qualitative difference in the action of the narcotics used. According to the concentration of the narcotic, he observed a weakening of the heart's action, more or less distinct arhythmia of the movements, and, with larger doses, a diastolic standstill of the heart. He never observed an increased action of the heart under any narcotic. In certain stages, especially in the beginning of narcosis, he found an increase of pulse-volume; in others, the number of heart-beats was increased. Either symptom, however, does not in itself constitute an increased action of the heart. The total work of the heart done in a given time must be taken into consideration, and an experimental proof that ether really does increase the absolute work of the heart, as is often claimed by clinicians, is still wanting.

From Dieballa's comparative studies of different narcotics we learn, as was already generally admitted, that chloroform is the most powerful heart-poison of all the narcotics. The isolated frog's heart was brought to a standstill by a solution of chloroform containing 0.126 per cent. To produce the same effect, ethyl bromid had to be used in 12 times, ether in 48, and alcohol in 192 times stronger molecular concentration. Besides the direct paralyzing effect of narcotics on the heart-muscle, the vasomotor centers are also affected. As a result of the decrease of the heart's action and the dilatation of the arteries, we see during narcosis a constant fall of blood-pressure of an amount varying with the substance used. For chloroform it is very characteristic, much less so for ether.

As to the pharmacological action of narcotics upon the central nervous system, a general rule may be laid down that the cerebrum is first paralyzed, then the spinal cord, and lastly the medulla oblongata. It is characteristic of a typical narcosis, at least in animals, that the respiratory center is last paralyzed, and that death is due to respiratory standstill. The majority of experimenters admit this general rule. Clinical experience, however, has shown us many cases of death under anesthetics, due to a primary standstill of the heart; controversy on this point is still sometimes very strong. That a primary standstill of the heart may be the cause of death may easily be explained by the direct action of narcotics upon the heart-muscle.

The general and gradual way in which narcotics paralyze the central nervous system has been given above, but the different narcotics show marked individual differences in their effects. Chloroform and ether act more or less in the same way. With ethyl bromid sensation is abolished very soon, but respiration stops almost as soon as reflexes disappear. Such individual differences exist for pentane, or amylene, as it was formerly called, for methylene chlorid, ethylene chlorid, and all the other narcotics that have been tried. For nitrous oxid it is charac-

teristic that complete surgical anesthesia is possible under ordinary circumstances only when atmospheric air is shut off. The individual characteristics of each of the narcotics influence, of course, its practical use. Some may therefore be safely used in minor surgery, which would be absolutely useless, or even dangerous, for major operations.

In concluding, the writer would like to draw attention to the so-called postnarcotic changes produced by anesthetics. By long-continued use of chloroform, fatty degeneration of internal organs has been caused (Saenger, Ungar, Juncker, Fränkel, etc.); and death occurring after successful narcosis and operation has been attributed to these changes. Recently, W. Selbach studied the after-effects of long-protracted ether narcosis. He found that ether could be regarded as causing almost no fatty degeneration. Dreser found after ethyl-bromid narcosis a constant excretion of bromin in the urine hours after the subject had recovered from the narcosis. He feels inclined to believe that ethyl bromid is persistently retained in the system and possibly transformed into a more poisonous substance. He explains thus the accidents which may happen after ethyl-bromid narcosis has been successfully accomplished. Dreser's observations give us one more proof of the greater toxicity of narcotics containing halogen.

SURGICAL ANESTHESIA, GENERAL AND LOCAL.

An anesthetic is an agent that abolishes sensation. It may be general or local. The former affects the entire system, and produces unconsciousness; the latter affects only that part of the body to which it is directly applied. Anesthesia, the state produced by an anesthetic, may be primary or complete. The former lasts but a few moments, while the latter may be prolonged indefinitely, at the will of the anesthetizer. The conditions of life or state of health, as regards age, injury, or disease, are few in which a judicious use of anesthetics may not safely be resorted to with benefit in case of necessity.

General Anesthesia.—General surgical anesthesia was demonstrated in public for the first time, and thus became an established, practical fact, at the Massachusetts General Hospital on Friday, October 16, 1846. The drug used upon that occasion was sulphuric ether. The administrator was William T. G. Morton. The operator was John C. Warren. The operation was the removal of a vascular tumor from the neck. It is a singular fact that during half a century's experience with anesthetics no safer or better agent for general use has been discovered; and furthermore, that the method of administration by means of the cone adopted in the early days of anesthesia is still in very general use, and is perhaps more commonly employed than any other special method.

The principal *general anesthetics* are ether, chloroform, and nitrous oxid gas. Various mixtures and combinations of these agents with each other, with alcohol, and with other substances have been, from time to time, suggested. Bichlorid of methylene, bromid of ethyl, pental, and other drugs have been employed, but none of them has gained the confidence of any considerable proportion of the profession. The two principal anesthetics the world over are ether and chloroform.

The former is in general use in the northern, middle, and western parts of this country, while in the southern portion and in most foreign countries chloroform is the favorite. Bichlorid of methylene was used to some extent in England at one time, especially by Spencer Wells. The agent used by him under this name was composed of 4 parts of chloroform and 1 part of methylic alcohol. The effects were practically the same as those of chloroform, even including the fatalities. Various compounds, such as mixtures of chloroform and ether, have been sold under that name, while the genuine chemical, bichlorid of methylene ($C_2H_2CI_2$), is devoid of anesthetic properties. For these reasons alone, this agent may very properly be considered as being unworthy of further attention. Bromid of ethyl (not ethylene, which is a very dangerous agent) resembles nitrous oxid in the promptness with which the patient passes under and out of its influence. The effect of the drug disappears in a few moments after the inhalation is stopped, leaving the subject in his usual condition. From the fact that several deaths have occurred from its use, and also that it is rather unstable, being changed by exposure to light and air to a dangerous compound, this agent will never supplant the older and more reliable anesthetics.

Various **anesthetic mixtures** have been, and are now, used to a limited extent all over the world. The most common one is the A. C. E., or "Ace of Spades" mixture. It is composed of alcohol, 1 part; chloroform, 2 parts; and ether, 3 parts, by measure. The "Vienna mixture" is composed of 1 part chloroform and 6 parts ether. The use of the various mixtures of anesthetic agents has never met with the approval of any considerable proportion of the profession, for the reason that their advantages over the single drugs are not sufficiently pronounced and decisive to lead to their adoption. In the writer's opinion, the rule of prescribing single drugs in the treatment of ordinary diseases, which has been recommended by many of our best therapeutists, applies with especial force to the use of anesthetics. It is a comparatively simple matter to estimate the effects of single drugs, while it may be very difficult or impossible to judge rightly of the effects of the same drugs when given in combination with others equally potent.

Dr. Schleich of Berlin has advanced the opinion that the absorption of a general anesthetic is dependent upon the surrounding temperature, and also upon the boiling point or maximum of evaporation of the agent employed. If the temperature of maximum evaporation corresponded to that of the body, then as much of the vapor would be exhaled as is inhaled at every respiration, and no narcosis would result. On the other hand, the higher the maximum point of evaporation, the more of the anesthetic is absorbed and the longer it remains in the system. Chloroform having a maximum point of 149° F., more of it is inhaled and retained at each inspiration than of ether, whose highest evaporating point is 93° F. To bring this maximum evaporating point nearer to the temperature of the body, Schleich has suggested three solutions by volume, as follows:

No. 1. Chloroform, 1½ ounces (48 gm.); petroleum ether (benzin), ½ ounce (16 gm.); sulphuric ether, 6 ounces (192 gm.).

No. 2 is the same as No. 1, except that it contains 5 ounces (160 gm.) of sulphuric ether.

No. 3 is composed of chloroform, 1 ounce (32 gm.); petroleum ether, ½ ounce (16 gm.); and sulphuric ether, 2½ ounces (80 gm.).

The advantages claimed for this method of anesthesia are saving of time in going under and coming out of its influence; the fact that less excitement, cyanosis, and mucous secretion result from its use, and also less vomiting and bronchitis. The absolute safety of these solutions is open to suspicion.

Sulphuric ether, the safest and best anesthetic yet discovered for ordinary surgical work, is made from sulphuric acid and alcohol. Absolute ether has a specific gravity of .718 at a temperature of 59° F., while that used for anesthetic purposes, as Squibb's, has a specific gravity of .725 at the same temperature. It is clear, colorless, very volatile; it has a pungent odor, and should leave no residue whatever upon evaporation. Ether should remain clear on adding a little oil of copaiba. This drug is best kept securely corked in tin, and in a cool, dark place. The vapor is more than two and a half times as heavy as atmospheric air (sp. gr. 2.58), while that of chloroform is a little more than four times as heavy. The fact should be constantly borne in mind that, owing to the inflammable nature of ether and its rapid vaporization, much the larger proportion of the vapor falls rather than rises. The slight amount of danger to be apprehended from the ignition of ether is shown by the fact that for more than thirty years the night surgery at the Boston City Hospital has been done under a six-light chandelier not over 3 feet above the patient's head, and no accident of this sort has ever occurred in consequence. Accidents from ignition of ether are rare, easily prevented, and should not militate in the least degree against its use.

Circumstances permitting, there are certain precautions to be taken before giving ether. The stomach should be empty, to avoid vomiting in the early stages of anesthesia. For this reason it is well for the patient to abstain from all solid food and from milk for at least six hours previously. A little bouillon, clear soup, or coffee may be taken a couple of hours before the inhalation; and in weak or exhausted people a little stimulant should be given by mouth or rectum shortly before the anesthetic. Another excellent plan in such cases is to give from $\frac{1}{12}$ to $\frac{1}{8}$ gr. (gm. .005–.008) of morphin sulphate under the skin, just prior to the ether. It steadies the nervous system, fortifies the anesthetic, and controls the pain to a certain extent when the effects of the ether pass away, thereby in some instances preventing the vomiting, a reflex symptom depending oftentimes upon the pain. The bowels and bladder should also be emptied, the former by means of an enema, and the latter by a catheter, if necessary. The patient should be dressed warmly and loosely about the neck and waist, to allow of free circulation and respiration. Great care should be taken throughout the period of unconsciousness to preserve the patient's body-heat, as this is one of the principal factors in the prevention of shock. Whatever anesthetic is selected, it should always be given in the presence of a third person, in order that the anesthetist may thereby receive any assistance necessary, and also that no unjust accusation may be brought against him afterward by female patients. Neglect of this rule has brought unmerited disgrace upon more than one innocent man in the past, by reason of erotic delusions, which are occasionally present under the narcotic.[1] It is his duty to thus protect himself, as well as the patient and her friends.

[1] A dentist in England was accused by a woman of criminal assault while she was under the influence of chloroform, although her father, mother, a physician, and the dentist's assistant were present during the entire period of narcosis (Turnbull, *Artificial Anesthesia*, p. 524).

Mode of Administration.—A great many different inhalers for giving ether have been devised from time to time, but, aside from economy in the amount of the drug consumed, they are of comparatively little use. Good judgment and a thorough knowledge of the process, derived from a proper training and experience, are the principal requisites of a good etherizer, and no form of apparatus yet devised can take the place of these attributes. As a rule, more skill and care are required in the use of the inhalers than in that of the cone and its modifications. The closed inhalers are pernicious from the fact that the air is breathed over and over again, becomes loaded with carbonic acid, and, at times, is apt to be too heavily charged with the narcotic, thereby producing cyanosis and other unfavorable symptoms. While these objections are less applicable to the open inhalers, yet both kinds are often so complicated or inefficient, without compensating advantages, that they have not received the general approval of the profession.

Special inhalers naturally find their chief field of usefulness in hospitals, where large amounts of ether are consumed.[1] With a good inhaler a skilful etherizer can save from 30 to 50 per cent. in the amount of drug required to accomplish the same work, as compared with the ordinary cone.

Of the numerous inhalers which have been brought out from time to time, mention may be made of Clover's, Ormsby's, and Leute's as examples of the closed varieties, and of Allis's and Blake's as types of the open kind. The latter open inhaler, now in use at the Boston City Hospital, is satisfactory from the fact that it is simple, cheap, easily used and cleansed, and accomplishes all that can reasonably be expected of any inhaler. It is a truncated, somewhat flattened tin cone, with an inflated rubber rim, and a wire frame inside, about which is wrapped a little ordinary gauze to hold the ether. This cone is readily cleansed by simply running hot water thrôugh it and putting in fresh gauze. With this apparatus a careful and skilful anesthetizer need not use over half the amount of ether that he would with the ordinary napkin cone.

From the earliest days of modern anesthesia, the most common method of administering ether has been upon a towel folded in the shape of a bowl, and stiffened with paper placed between the two outer layers, which also serve partially to confine the vapor. The straw cuff of the marketman is objectionable from the fact that it cannot be kept clean and fresh, which is of the greatest importance in the avoidance of "inhalation pneumonia." Every patient should take his anesthetic, whatever it may be, from a thoroughly clean and fresh inhaler, as no other is either safe or decent. The principal objection to the napkin is the unnecessary amount of ether wasted. This is best obviated by having the sides of the inhaler made of an impervious material, such as tin, while the opening at the top should be sufficiently large to allow a free ingress of air. There should be a generous air-space—50 to 60 cubic inches—about the mouth, in order that the patient may be spared the sensation of insufficient room for breathing. A free and easy circulation of air through the inhaler, whatever its shape or kind, is indispensable to a satisfactory apparatus. Pure air charged with ether-vapor, in the proper proportion—best estimated by its effects upon the patient—is the most desirable mixture for safe and efficient anesthesia.

[1] The cost, at wholesale price, of the ether used at the Boston City Hospital in 1896 was about $2300.

The patient, warmly and loosely clothed, should lie in an easy position upon his back, with his head moderately raised. False teeth, tobacco, gum, and any other foreign substance should be removed from his mouth. A basin, gag, tongue-forceps, and towels should be at hand, and all preparations for the operation, or whatever is to be done, should be made out of the patient's sight and hearing. Everything in his room should be done quietly, without excitement or confusion. He is to be assured that although the vapor is not pleasant, yet it is perfectly safe; that plenty of time will be given him; that he shall not be hurried, and that nothing will be done until he is sound asleep. He is to be instructed not to resist, but to resign himself readily to the influence of the drug, to close his eyes, and to breathe naturally through the nose or mouth, as is most agreeable to himself.

At first, the inhaler should be held about a foot from the face, and gradually brought nearer, as he becomes accustomed to the vapor. The cardinal rule to be observed in administering ether is never to give it in such concentration as to interfere with natural respiration or cause coughing, choking, or holding of the breath. All of these symptoms rapidly disappear upon allowing a few breaths of fresh air. The inhaler, after being replenished with ether, should not be placed as close to the face as before, but gradually returned to its former position, thereby avoiding the overwhelming effects of the vapor, as indicated by coughing and efforts to get away from it. The natural regular respiration affords the best means of saturating the system with the anesthetic, and its employment is attended with the least unpleasant effects. The custom of constantly nagging or urging the patient to breathe deeper or faster is not judicious, as neither time nor comfort is gained thereby. It would be well for every physician to inhale ether once to the point of unconsciousness, in order that he might fully appreciate the importance of giving the drug carefully and slowly. The dreadful sensation of suffocation, which in the vast majority of cases is avoidable, leaves upon the patient's mind a lasting antipathy to the agent.

Except in the case of very young children, hasty or forced etherization in the early stages is unnecessary and cruel, and may be harmful. Too sudden application of the vapor irritates the mucous membrane of the air-passages, excites spasm of the laryngeal and respiratory muscles, and closes the glottis, thereby inducing the horrible sensation of suffocation. The patient naturally struggles for fresh air according to his strength, and more or less brute force is required to restrain him within bounds. Aside from the alcoholic, the hysterical, and the extremely nervous people, these unpleasant manifestations are entirely unnecessary and avoidable. The great majority of patients can be put under the influence of ether in from ten to twenty minutes with little or no restraint, and without undergoing the disagreeable experience of impending suffocation. Patience, good judgment, proper training, and experience are the chief requisites of an efficient etherizer.

The indications of complete anesthesia are stertorous respiration, muscular relaxation, as shown by moving the arms without provoking resistance, and absence of corneal reflex. The latter test should be resorted to as little as possible, as a troublesome conjunctivitis occasionally follows its abuse.

The primary object of anesthesia being the prevention of pain, complete muscular relaxation is in many cases unnecessary. The patient knows nothing and feels nothing, and for these reasons many operations can be well done without his being etherized to the point of absence of all reflex muscular movement. In the reduction of dislocations and in various other manipulations, more or less complete relaxation of the muscles is essential; but in many operations, there can be no doubt, more ether is given than is really necessary, thereby needlessly prolonging the narcosis, increasing the unpleasant after-effects, and often adding to the shock and prostration. One of the principal objections to the use of any anesthetic is the fact that the operator may thereby be led to ignore the flight of time, to the detriment of the patient. It is true, in a general way, that the shorter the duration of an operation and the smaller the amount of ether given the better. Ether is primarily a stimulant, but after a time, varying greatly in different people, as regards age, natural vigor, present condition, and so on, it ceases to act in this manner, and if carried too far may aid in producing exhaustion or even collapse. The respiration then becomes shallow and sighing, the skin cyanotic and bathed with profuse sweat, the pulse weak and irregular, and the patient is reduced to a state of great danger. To avoid this unfortunate condition of affairs, so far as the anesthetic is concerned, it is better frequently to interrupt its administration by giving fresh air, and allow the patient to rally partially from the effect of the drug. A few whiffs of ether now and again will keep him free from pain, anxiety, and fright. As he knows nothing and will remember nothing, a moderate amount of involuntary struggling unattended with suffering does no harm, while the danger of prostration and collapse will be reduced to a minimum. With suitable precautions, capital operations upon very frail and exhausted patients can frequently be done successfully. All preparations having been made, the patient is carefully etherized, and the operation—an amputation, for example—is quickly done. The ether is removed when the bone has been divided, and while the vessels are being secured and the wound closed a few whiffs of the anesthetic are given occasionally. The result is that by the time the dressings are completed, the patient has nearly recovered from the narcotic, and is free from the symptoms of alarming prostration that so frequently follow the same operation when unduly prolonged. The smaller the quantity of ether given in severe or prolonged operations, compatible with the objects to be attained, the better for the patient. This matter is of a good deal of importance, and does not always receive the attention it deserves. The patient once having been etherized, the rule to be borne in mind is the saving of time, blood, animal heat, and anesthetics.

While recovering from the influence of any anesthetic, no person should be left alone for a moment, until he is conscious of his condition. This rule is of special importance in the care of the very old and feeble, of the very young, and of those who have undergone a severe or prolonged operation. Accidents from vomiting and choking are possible, but more important is the danger of sudden collapse, which calls for prompt measures for relief. Upon the appearance of symptoms suggesting this condition, the patient should be well covered,

and surrounded with warm, but not hot, bottles. The foot of the bed or table should be raised about a foot; stimulants, such as brandy and coffee, should be given per rectum, as the stomach acts slowly, if at all, while the patient is in this condition. Strychnin, atropin, morphin, or digitalis, with or without brandy or cologne spirit, which is of nearly the same strength as absolute alcohol, should be given under the skin. The room should be darkened, quiet enjoined, and sleep encouraged. These measures will usually suffice to rally the patient from danger and put him on the way to recovery.

Rectal Etherization.—It was thought at one time that rectal etherization might prove feasible in operations about the face and throat. It was soon found, however, to be difficult or impossible to regulate the dose satisfactorily. The narcosis might be too profound or too prolonged, the bowels become distended, and the mucous membranes so irritated as to give rise to tenesmus and bloody stools. For these reasons the method has never found favor with the profession.

A very good method of continuing the etherization in operations about the mouth and face is to force the vapor through the nose by means of a tube and bulb. The apparatus devised by Souchon of New Orleans is a good one for this purpose. The patient is first etherized in the usual manner; then the tube having been passed through one nostril into the pharynx, the air is pumped through the ether in sufficient quantities to keep up the proper degree of narcosis. In operations attended by danger of suffocation from blood trickling down the throat, it is better and safer first to perform tracheotomy, plug the pharynx, and continue the etherization through the tracheal tube. All danger from strangulation is thus avoided.

Certain unpleasant or even serious events may occur to the patient in taking ether, which will now receive consideration. The inflammable nature of the drug and the precautions necessary to be taken in consequence have already received attention.

Should ether be given upon a full stomach, the respiration may not become free and regular until vomiting has taken place, after which no further trouble need be expected from that source. No danger is to be apprehended from vomiting during or after etherization, except the danger of undigested food being drawn into the trachea. This accident has happened and has caused death, but it is one of the rarest of fatalities, and is probably as common without as with an anesthetic. The treatment is an immediate tracheotomy, provided the offending materials are not at once ejected by the natural efforts of the patient. While vomiting, the patient should be turned upon his side, the mouth opened, and close watch kept of the respiration and color to see that the larynx and trachea are free. It is believed by good authorities that $\frac{1}{200}$ to $\frac{1}{100}$ grain of atropin sulphate, given under the skin a short time before ether, lessens the subsequent nausea and vomiting very materially. Hare recommends the following for this purpose: A mixture of 1 grain each of acetanilid, monobromated camphor, and caffein citrate, given every hour for six or eight doses. It is to be remembered that the air-passages of old people are much less sensitive to the presence of blood, mucus, and all foreign substances, than are those of the ordinary adult, and hence that they require special attention in this regard while under the influence of anesthetics.

The administration of oxygen immediately after the removal of the ether is a favorite practice with many physicians, who claim that the period of recovery from the anesthetic is thereby shortened, and also that the nausea and vomiting are much diminished. It is given from a flask, different sizes of which are in the market. From ten to fifteen minutes is usually a sufficient time for its exhibition, and about 25 gallons of the gas are consumed. It is conducted through a bottle of water and directed upon the face of the patient until he has fairly recovered from the ether.

Another occasional complication in giving ether is the free secretion of mucus. This occasionally results in edema of the lungs, and threatens suffocation. It is most often seen in fat and elderly patients inclined to chronic bronchitis or asthma, or in those having a weak heart, or suffering from exhaustion, as from a strangulated hernia of long duration. These patients can usually take ether with safety, if due care is exercised to avoid giving too much. They are to be kept just on the verge of complete anesthesia, and allowed plenty of pure air. A hypodermic injection of atropin sulphate, $\frac{1}{150}$ to $\frac{1}{100}$ grain, given half an hour before the ether, would not only tend to check this over-secretion of mucus, but also act as a desirable stimulant to the respiratory center. The action of chloroform in these cases is more satisfactory than ether. The treatment of this complication consists in removing the ether, opening the windows, fanning, and artificial respiration, great care being taken to insure a free passage of air into the lungs. On re-establishing the respiration, the cyanosis will quickly disappear, and the patient is safe. Should the heart show signs of failing, $\frac{1}{60}$ to $\frac{1}{20}$ grain of strychnin sulphate should be given under the skin. Stimulants may also be given in the same manner.

Temporary interference with breathing during the later and deeper stages of ether narcosis, due to relaxation of the muscles of the throat and closure of the glottis from falling back of the tongue and epiglottis, is not infrequent. Although violent efforts on the part of the diaphragm continue to be made, yet the cyanosis and deep congestion of the face plainly indicate that no air enters the lungs. This state of affairs is not at all alarming or serious, provided proper measures be taken for relief. They consist in opening the mouth and drawing forward the tongue in such a manner as to raise its base, and with it the epiglottis, thereby allowing the air to enter the lungs. With an efficient gag between the teeth, the tongue may be drawn out with forceps, care being taken to avoid undue violence to that organ. Its base is thereby raised, and with it the epiglottis, allowing a free ingress of air. Another method of accomplishing the same object is simply to flex the head upon the chest, and by the action of the styloid, and probably other muscles, to open the glottis. Pressing the lower jaw forward, partially dislocating it upon the articular eminences, is also another favorite method of securing a free passage of air through the larynx. In addition to this maneuver, Hare recommends that the head be extended in such a manner as to bring the fauces, larynx, and trachea into a direct line. Too forcible or persistent pressure behind the angles of the lower jaw may not only leave an uncomfortable soreness, but may lead to inflammation of the parotid.

A tetanic spasm of the respiratory muscles occasionally occurs, but is overcome readily by removing the ether, opening the glottis, fanning the patient, and, in extreme cases, by resorting to artificial respiration. This is a somewhat rare complication.

It is very seldom, indeed, that tracheotomy is required for any accident due to the ether alone. It may be necessary for edema of the larynx or for food in the trachea, but these complications are extremely rare. A more common danger is the escape of blood into the air-passages during operations about the mouth and nose. This may occur very insidiously, and the first warning given may be cessation of breathing. The blunted sensibility of the air-passages may have prevented any warning cough or choking, a condition peculiar to elderly or very weak and exhausted persons. This event calls for prompt and energetic treatment. The trachea is to be opened at once, an elastic catheter carried down into the bronchi, and air forced into the lungs, for the purpose of driving out the blood. Suction does no good. Nature does not clear the bronchial tubes in this manner, neither can the surgeon. Artificial respiration and hypodermic stimulation may also be necessary to revive the patient. This accident is not peculiar to ether any more than to any other anesthetic, but the possibility of its occurrence should be recognized, and proper measures taken to meet it promptly and efficiently.

Death *from* an anesthetic is a very different thing from death *under* an anesthetic. In the former case, the drug is the principal cause; while in the latter, it may have little, if anything, to do with the result. No anesthetic yet discovered is entirely free from danger under all circumstances. In considering the relative safety of ether and chloroform in this article, only those cases devoid of danger in themselves will receive attention, for the reason that it is difficult or impossible to determine the exact influence different factors may have in producing the result in patients exhausted by hemorrhage or disease, or prostrated by the shock of an injury or of long severe operations. The treatment of those cases is attended with more or less danger, whatever anesthetic is used and however carefully it may be given. Therefore, they are not suitable ones upon which to base an estimate as to the relative safety or danger of these drugs. A person in ordinary health desiring a minor operation, such as incision of an abscess, extraction of a tooth, or correction of a strabismus, inhales a few whiffs of an anesthetic, and with little or no warning stops breathing, the heart stops, and he is dead. An autopsy fails to reveal any adequate cause of death; the only rational conclusion possible is that death was due to the anesthetic. Pure ether of high grade carefully given never kills healthy people. Chloroform occasionally does, and in just the manner and under just the circumstances that are indicated above. About 40 per cent. of the fatalities from chloroform occur in reasonably healthy persons about to undergo a minor operation which in itself lacks the element of danger. The unfortunate result also takes place, in many cases, in the early stages, or before anesthesia is complete, also in cases where the patient has previously taken the drug safely. No blame, in many instances, can be attached to the quality of the agent or to the method of administration. The accident has occurred in the hands of the most careful and experienced men, such as Sir James Y. Simpson, the father of chloro-

form anesthesia, Erichson, Billroth, Volkmann, Syme, Hunter McGuire, Willard Parker, F. H. Hamilton, Alden March, Moses Gunn, W. W. Dawson, and many other competent and reliable physicians. Surely, an agent that is not safe in the hands of such men cannot be implicitly relied upon in the hands of the ordinary practitioner. In this capricious, treacherous action of chloroform lies its chief danger as an anesthetic for ordinary use.

Pure anhydrous sulphuric ether never acts in this manner. So far as the writer knows or has been able to ascertain, this sort of fatality from ether has never occurred in any of our hospitals or in this vicinity. The drug has its disadvantages and its dangers, but there is plenty of warning, and timely measures almost always overcome the difficulty. Very different is the course of events in accidents from chloroform. Not only are the symptoms of danger sudden in their onset, brief in duration, or entirely absent, but all efforts to resuscitate the patient are, in many instances, unavailing. According to the most reliable statistics, chloroform causes death in about 1 in 2000 cases. The aggregate is large, however, by reason of the great numbers who have occasion to use the drug. Its victims can be numbered by hundreds, if not by thousands, during the half-century of its use as an anesthetic. "Last year (1897), in England alone there were 96 published deaths, and no one can tell how many unpublished deaths," from this agent.[1]

Much has been written as to the exact manner in which death occurs under the influence of these two drugs. The common opinion is that ether kills slowly by asphyxia, while chloroform kills quickly by cardiac paralysis. The weight of evidence goes to prove that ether is primarily a stimulant to the circulation, and that chloroform is a cardiac depressant; that the former may paralyze the respiratory centers and the latter the cardiac; and in consequence of those opinions, it is claimed by some that in giving ether only the breathing needs attention, while in the use of chloroform the pulse is all that requires watching. The patient cannot be watched too carefully in all particulars while under the influence of any agent powerful enough to abolish consciousness. No one function should receive attention to the exclusion of the others. It makes little difference to the victim or to his friends whether the breathing or the heart stops first, the result is alike disastrous. This question has been most thoroughly investigated, not only by individuals, but by committees and by commissions, and yet "the practical fact which stands out in terrible distinctness is that death under chloroform has not lessened, in spite of physiology and Hyderabad Commissions."

The Boston City Hospital has been in existence a third of a century. During this time, over 63,000 persons have been treated in the surgical wards of the institution. More than 27,000 of those cases were due to accidents or other injuries. About 23,000 operations, of all kinds and descriptions usually met with in a large metropolitan hospital, have been performed upon those patients, to say nothing of a large number performed in other departments of the hospital and upon out-patients. Practically all of this operative work has been done under ether anesthesia. There has never been a death in this hospital from ether alone.

[1] A. D. Waller, *Brit. Med. Jour.*, April 23, 1898.

Every fatality that has occurred under this agent has been due more largely to other factors, such as shock, hemorrhage, exhaustion, uremia, etc., than to the anesthetic itself. Death during a minor operation upon a fairly healthy person has never occurred in this institution.

More than 35,000 operations have been performed under ether at the Massachusetts General Hospital, the birthplace of anesthesia, since that eventful Friday in 1846. So far as is known, not a single person of this large number has perished from the anesthetic alone. The two largest hospitals in Boston, therefore, have upon their records over 58,000 ether operations, without a single fatality due solely to the anesthetic. The experience of the smaller hospitals and of operators in private practice in this vicinity is no less favorable. Such being the facts, can there be any reasonable doubt as to the relative safety of ether and chloroform? Until testimony equally favorable to the latter agent has been produced, it would seem wise to consider that question settled.

The comparative merits of ether and chloroform may be briefly stated as follows:

Ether is slower in its action, less pleasant to inhale, more bulky and more expensive, inflammable, more or less irritating to the air-passages, and is often followed by nausea and vomiting; but it is safe under all ordinary circumstances, and, when pure and properly given, never results fatally in reasonably healthy people.

On the other hand, chloroform, which is seven times as strong as ether (Waller), is quicker in its action, more pleasant to take, less irritating to the mucous membranes, less bulky and less expensive, not explosive, and is usually attended by less nausea and vomiting; but it is not always safe. Occasionally, death occurs in healthy persons early in the administration of this agent, even when pure and carefully given, and the most searching post-mortem examination fails to find any other satisfactory explanation of the unfortunate occurrence. These facts being fairly well established, it would seem to be incumbent upon those who use chloroform as an anesthetic in ordinary surgical work to be prepared to justify their action in case of accident plainly due to the drug itself.

The fact that ether is safer than chloroform is gradually being recognized in many foreign countries, and its use is slowly but surely spreading among the more enterprising portion of the profession. Owing to its volatility, its high cost, and the difficulty experienced in keeping it for any length of time in very hot climates, it will probably never come into general use in the tropics. Twice as much of the drug and double the length of time are required in India, for instance, to produce ether anesthesia, as compared with this country. Its bulk and comparative slowness of action will preclude its use to a considerable extent in military surgery in actual war, when transportation and time are of great importance. The field surgeon, surrounded by hundreds of wounded anxiously waiting for speedy relief, must select the agent that acts most quickly and that can be most readily obtained. It is estimated that anesthetics were used in no less than 80,000 instances during the War of the Rebellion. Chloroform was the agent selected in about three-fourths of the cases. The quantity required varied from $\frac{3}{4}$ dram to 96 drams, the average being 11 drams. The

amount of ether ranged from 2 to 25 drams; the average was 51 drams. The time consumed in producing chloroform anesthesia averaged nine minutes, while ether required, on an average, sixteen minutes. The vomiting was less frequent and of shorter duration after chloroform. Death was ascribed to chloroform in 5.4 cases, and to ether in 3 cases. per 1000. The advantages of chloroform over ether in military surgery in the field are very pronounced, and cannot be offset by the comparatively small percentage of increased danger. In civil life these arguments do not obtain.

While ether is the safer agent for ordinary surgical work, yet there are certain conditions in which chloroform is to be preferred for special reasons. Those operations liable to be complicated with spasm of the glottis, edema of the larynx or lungs, or a profuse secretion of fluids in the air-passages, can be done better and more safely under chloroform. This agent, therefore, is to be preferred in the following affections: Membranous croup, acute or chronic laryngitis, edema of the glottis or lungs, injuries to the larynx, deep cervical cellulitis, malignant disease of the throat or anterior portion of the neck, tumors situated deeply in the neck—as bronchocele—foreign bodies in the air-passages or in the esophagus, chronic bronchitis, asthma, and emphysema. Tracheotomy and esophagotomy, as a rule, are more easily and safely done under chloroform, as there are less spasm and less secretion. The latter agent also produces less congestion of the vessels of the face and neck.

Patients having advanced disease of the kidneys are poor subjects for either agent, but many writers claim that there is less irritation of these organs, and therefore less danger, under chloroform than under ether. It is also said that chloroform causes less pressure in atheromatous blood-vessels, and hence is to be selected in cases supposed to be liable to apoplexy. This accident is so very rare under ether, that the opinion would seem to rest largely upon theories resulting from physiological experiments. Advanced cases of heart disease may take ether carefully with reasonable safety. Operations under any of these conditions are attended with a certain amount of danger, aside from the influence exerted by any anesthetic. The smallest possible quantity should be given, and the utmost care taken in the administration.

Bronchitis and pneumonia seldom result in this vicinity from the administration of ether. The complication is too rare to be considered in choosing an anesthetic. Two factors call for careful investigation in connection with this subject—namely, the quality of the ether and the exposure of the patient. Certain brands of this drug are unfit for use by reason of their very irritating qualities and comparatively small narcotic properties. This matter is of so much importance that many surgeons in this part of the country will use only Squibb's ether, than which, probably, no better has ever been made.

The preservation of animal heat merits careful attention. It is a fact familiar to all that persons are more susceptible to cold when asleep than when awake, and Dudley P. Allen's experiments upon dogs, as well as his observations upon patients, go to show that the body temperature is lowered under prolonged anesthesia. Loss of animal heat tends toward collapse, hence the great importance of keeping patients well covered during anesthesia. Exposure of any considerable

portion of the body usually covered and the application of wet cloths are fraught with danger, and may be accountable for a certain proportion of the cases of post-ether bronchitis and pneumonia. Patients who are properly protected and who inhale a high grade of sulphuric ether administered in a judicious manner have little to fear from any affection of the respiratory tract as a result of the anesthetic.

Primary anesthesia[1] has a limited field of usefulness in surgery. Under its influence simple incisions may be made, sutures and drainage-materials may be removed, and various other brief operations or manipulations can be carried out with satisfaction to the operator and without suffering to the patient. It is induced in the following manner: Everything being in complete readiness, that no time need be lost at the important moment of temporary anesthesia, the patient is directed to inhale the ether vapor by drawing in a few deep breaths. From a dozen to twenty are often sufficient to produce the desired effect. The falling of the hand, which the patient has been directed to hold in the air unsupported, is a good index of the right moment to proceed with the operation. Except in extremely nervous people, this method is very satisfactory in suitable cases. Little or no pain is experienced, fright is largely removed, consciousness returns at once, and there is neither nausea nor vomiting. The patient is in his usual condition in ten or fifteen minutes, and, except for the modified pain of an incision, for instance, he goes about his business as if nothing had been done. In its effects and duration this form of anesthesia resembles that of nitrous oxid gas, but it is more convenient for the general practitioner, from the fact that no special apparatus is necessary, and the agent is always at hand or is easily obtainable. The method is worthy of a more extensive use than it has ever had at the hands of the profession at large.

Local anesthesia[1] has considerable value, and may be depended upon for slight operations, such as simple incisions, the removal of small tumors or growths in the skin, etc. More pretentious operations, such as castration, strangulated hernia, laparotomy, and others of equal magnitude, have been done under its influence; but, except in rare instances and for special reasons, general anesthesia is preferable for this sort of work, and is so considered by the profession. In cases, however, where the patient's condition, owing to pulmonary disease or other causes, does not admit of etherization, local anesthesia has a distinct field in the performance of major operations. While local agents may control the pain, they do not remove the dread of the operation, hence the patient cannot always be depended upon to keep quiet, which in many instances is an important factor of anesthesia.

The principal local anesthetics are cocain hydrochlorate, which stands at the head in efficiency; eucain, similar to the preceding agent, but less poisonous; ethyl chlorid; rhigolene, not much used at present; carbolic acid, very superficial in its action; ether spray; and ice, or ice and salt. The field of usefulness of all the freezing agents is rather limited, from the fact that while sensation is at first much diminished, yet the discomfort of returning sensation is often as great as would be that of the operation itself. They are useful in removing wens from the scalp, but not, as a rule, from other regions of the body; in tapping

[1] See also the chapter on Minor Surgery.

the abdomen; in simple incisions, as for a superficial abscess, but not for a felon or palmar abscess or for any deep and highly inflamed tissues.

Ethyl chlorid[1] is one of the most convenient of this class of agents for ordinary use, from the fact that, as it is put up in small glass flasks, it is only necessary to remove the cap and direct the spray from a point about 10 inches away upon the part desired to be frozen, which, in the space of a minute or so, turns white and is benumbed sufficiently to allow of any of the above specified things being done with little or no pain. The same result can be obtained with ice alone, or with ice and salt. Rhigolene and ether are to be applied in the form of spray, but are inferior to the above-mentioned agents, as their action is not so easily confined to the precise area. It is to be remembered that care and judgment are always to be exercised in applying cold as well as heat to the body, as ulceration and even sloughing may be produced almost as readily with one class of agents as with the other.

Cocain, the alkaloid from the leaves of coca—a shrub which grows in Peru and Bolivia—was discovered by Gaedeke in 1855, but it has been in general use as a local anesthetic only about ten years. Dissolved in water in the proportion of 1 : 1000 or 500—*i. e.*, a strength of from $\frac{1}{10}$ to $\frac{1}{5}$ per cent.—the hydrochlorate of cocain is probably the best local anesthetic known to the profession to-day. There are two precautions to be borne in mind in using this agent. The first is the marked depressing action upon the heart and brain, and the other is the pernicious appetite which may be established for the drug. The cocain habit seems to be more powerful than that for morphin, and it is more difficult to break up and eradicate. Given in the proportions and for the purposes mentioned in this article, there is very little danger to be apprehended from the use of this valuable drug. The agent is probably as efficacious when it is dissolved in water and used alone as when given with morphin, atropin, or other narcotics. Applied to mucous membranes, it is readily absorbed, exerts its specific effect in a short time, and produces an anesthesia lasting about a quarter of an hour. The effects of this drug vary not only in individuals, but also in different regions of the same person, some being much more susceptible to its influence than others. The mucous membrane of the eye appears to be especially sensitive to its action, and therefore the agent is of especial value in operations and manipulations of this organ. The same may be said of the nose and throat. The action of cocain upon the lining of the urethra is neither quite as safe nor as satisfactory as upon the organs above mentioned. Fatal results have followed its application to this region (Hare, Park's *Surgery*); hence very weak solutions should be used in the urethra and nose, not over 2 per cent., and they may well be even weaker than this at first. For the eye a 2 per cent. solution is often strong enough, but for the vagina and rectum a 10 per cent. strength may be required.

Infiltration Anesthesia.[1]—For operations involving the skin and subjacent tissues, the method of producing local anesthesia by infiltration, as proposed by Schleich of Berlin in 1891, is probably the best yet suggested. By this method, it is said, all tissues except inflamed bone can be rendered anesthetic. The technic is simple, the solution is

[1] See also the chapter on Minor Surgery.

weak, and the results are usually satisfactory. The site of the injection is to be washed with soap and water, and then with bichlorid solution, 1 : 5000; the syringe is to be boiled; in short, aseptic precautions are to be carried out as in ordinary minor surgical operations. The solutions suggested by Schleich are of three strengths. The medium and most useful one contains 1 grain cocain hydrochlorate, $\frac{1}{2}$ grain morphin hydrochlorate, and 2 grains common salt to 1000 minims of water. The stronger solution, for use in inflamed tissues, contains double the amount of cocain; and the weaker, $\frac{1}{10}$ grain of the drug. The tablets of Wyeth and Brother, made in accordance with the above schedule, are the most convenient form for common use. To produce anesthesia of the skin, it is necessary to inject the cocain *into*, and not *under* it, as the peculiar influence of the drug does not permeate the skin from the cellular tissue. The anesthetic area is white, more or less edematous in the form of wheals, and about $\frac{1}{2}$ inch in diameter. The effects of the agent last from fifteen to twenty minutes, and are more pronounced when it can be confined to the part by an elastic band, as in a finger, toe, or the penis. To render inflamed tissues anesthetic, it is necessary to surround them by a zone of narcotized healthy skin, and from that to extend the injections into the desired area. It is doubtful if this process has any advantages over primary or general anesthesia in operating upon inflamed structures. The mental peculiarities of the individual must be taken into account. Very many people would not care to undergo the mental strain of realizing that an operation was being performed upon them. Judgment, tact, and skill are requisite in the use of those agents, in order that the greatest benefit may be derived from their application.

Eucain, as a substitute for cocain, has been employed to some extent as a local anesthetic in the strength of 1 to 2 per cent., and to the amount of $1\frac{1}{2}$ grains and upward. "Eucain B" is said to be less irritating than "Eucain A," but the limit of safety has not been accurately determined. The advantages claimed over cocain are the lessened danger of cardiac depression, the longer duration of the narcosis, and that neither time nor heat impairs its strength, thus allowing the solution to be boiled before using. Heat impairs the cocain solutions.

The anesthetic influence of eucain is slower in its manifestation than it is from the other agent. The most damaging report about it is of the frequent occurrence of local sloughing in operations "in fatty tissue, upon the fingers and toes, the prepuce, and bursal and tendon sheaths." In consideration of the very minute quantity of cocain required in cases suitable for local anesthesia, it hardly seems to the writer that the claims for the superiority of eucain over the former agent have been proved. Further light on this subject is desirable.

Holocain.—Hasket Derby of Boston has used holocain for over a year in his operations upon the eye, and has come to the conclusion that, applied locally, it produces a greater degree of anesthesia than cocain, and proves efficient in certain cases of painful inflammation in which the latter drug fails. Holocain (1 per cent. solution) is strongly bactericidal in its action, and has been used with great satisfaction in many cases of painful corneal ulcers. Applied locally, holocain produces no constitutional symptoms, but it is too poisonous to be taken internally or to be injected into the tissues.

NITROUS OXID; NITROUS OXID AND OXYGEN; NITROUS OXID AND ETHER; CHLOROFORM-MIXTURES.

The anesthetics commonly employed in England at the present time are nitrous oxid gas (either alone or mixed with oxygen), ether, chloroform, and mixtures of ether and chloroform in various proportions.

Nitrous oxid is largely used for dental and other short operations requiring only brief anesthesia. Its chief advantages are 1. Its great safety; 2. Absence of the necessity for elaborate preparation of the patient; 3. Speedy induction of anesthesia; 4. Quick recovery without unpleasant after-effects.

It can safely be, and generally is, administered to patients sitting upright in a chair, the head being perfectly supported and as nearly as possible in a line with the body. No food should be taken immediately beforehand, though it is not necessary to insist on a fast of several hours, as in the case of ether and chloroform. Care must be taken that the clothing is quite loose around the neck, chest, and abdomen, so that no obstruction to respiration shall be present. Any movable artificial teeth should be removed from the mouth, and for dental operations a small prop must be inserted on the side of the mouth opposite that on which the operation is to be performed.

Several forms of apparatus are used in England for the administration of nitrous oxid; that of Frederic Hewitt is very commonly employed, and is satisfactory and convenient.

FIG. 185.—Hewitt's nitrous oxid apparatus.

B is an india-rubber bag of two gallons' capacity, into which the gas passes from the cylinders *C*, *C*. At the upper end of the bag is the stopcock *SC*, containing an inspiratory and an expiratory valve. When the small handle *h* is in the position shown in the figure, the contents of the bag are shut off from the stopcock and face-piece, so that the patient breathes only air, inspiring and expiring through the valves. When the handle *h* is pushed up, the bag is put into connection with the stopcock and the patient inhales gas from the bag, and expires into the air, still breathing through the valves. The handle *d*, at the end of the stopcock, works an inner casing which carries the valves, and the arrangement is such that when *d* is turned round, the valves are put out of action, and the patient simply breathes into and out of the bag. The bag is first nearly filled from the cylinder by turning the foot-key, and the face-piece applied to the patient's face. He is then told to breathe deeply and regularly, and gas is admitted by means of the handle *h*.

The foot of the administrator is kept on the foot-key, and a steady stream of gas is allowed to run into the bag. The valves are usually allowed to act throughout the administration; but in some cases, where a rather longer anesthesia is required, the handle *d* is turned round toward the end of the administration, and the patient is thus caused to rebreathe the gas which he has expired. As the inhalation proceeds, the respirations become deeper, and finally stertorous, the face gets dusky, and muscular twitchings of the limbs and body occur. When anesthesia is complete, the pupils are more or less dilated and the conjunctiva insensitive to the touch. The face-piece is now removed and the operation is performed. The time taken to produce anesthesia is generally from thirty to sixty seconds.

The chief objection to the use of nitrous oxid alone is the occurrence of symptoms of asphyxia, due to the deprivation of air. These symptoms are—1. Cyanosis; 2. Stertor; 3. Jerking of the muscles.

They are especially apt to occur in children and anemic persons, who also "come round" very quickly, giving a very short period of efficient anesthesia. The muscular twitchings, too, are sometimes so excessive as seriously to interfere with the operation. In the case of very anemic women, there is, besides, a certain danger of respiratory or cardiac failure during the administration of nitrous oxid alone; and in old people with atheromatous arteries there may be some risk, owing to the strain thrown on the circulation. The asphyxial symptoms may be diminished or abolished by giving a few breaths of air during the administration. But a more accurate method is that of Hewitt, in which a small quantity of oxygen is gradually mixed with the nitrous oxid by means of a specially devised apparatus. With this it is possible to increase or diminish the oxygen by very small amounts, so that the amounts inhaled are accurately under the control of the administrator. The advantages of this method, which is now extensively employed in England, are—

1. The elimination of the asphyxial symptoms mentioned above, with the production of tranquil anesthesia.

2. A longer period of anesthesia available after the face-piece has been removed.

Hewitt gives about forty-four seconds as the average period, as against thirty-five seconds with nitrous oxid alone.

B is a large india-rubber bag, divided into two equal compartments which do not communicate, one for nitrous oxid, the other for oxygen. The respective gases pass from the cylinders *C, C, C* into the compartments of the bag on turning the foot-keys *K, K*. The tube conveying the oxygen passes inside that conveying the nitrous oxid for nearly the whole distance, but the two separate on reaching the bag. To the upper end of the double bag is fitted the most important part of the apparatus—viz., the stopcock through which the gases pass on their way to the face-piece. The tubes *t, t* of this stopcock are each provided with a valve acting during inspiration, so that the gases do not mix before reaching the mixing chamber *MC*. This chamber occupies the greater part of the stopcock, and to it the gases are admitted by moving the handle *h*. When the pointer of this handle points to the word "Air" on the dial-plate *d*, air only can be breathed; when it is moved round so as to point to "N_2O," nitrous oxid is admitted, and, as it travels further, oxygen enters in addition. The nitrous oxid enters the mixing chamber directly from the tube *t*. The oxygen first enters the oxygen-chamber *oc*, and thence passes to the mixing chamber through a series of ten small holes, which are opened one by one as the handle *h* is moved round, and are indicated by the figures 1 to 10 on the dial-plate. Between the mixing chamber and the face-piece *F* are two valves, one acting during inspiration, the other during expiration, so that if the face-piece fits properly, the patient must inhale from the apparatus and expire into the air. The two compartments of the bag are first nearly, but not quite, filled with the respective gases, the pointer of the handle pointing to "Air." There should not be a positive pressure in the bag. The face-piece is then accurately applied, and the patient told to breathe deeply and regularly. The handle is now turned so as to admit nitrous oxid, and then immediately to 1 or 2 on the dial-plate. The patient is now breathing nitrous oxid with a very small per cent. of oxygen. The proportion of oxygen admitted to the mixing chamber

is so small that the quantity first let into the bag is quite sufficient for an administration, and no further supply from the cylinder will be needed, but a constant stream of nitrous oxid must be admitted to the bag, by means of the foot-key, to supply the place of that inspired and expired by the patient. In this way the compartments of the bag can be kept equal in size throughout the administration, a point which must be carefully attended to.

FIG. 186.—Hewitt's nitrous oxid and oxygen apparatus.

The amount of oxygen given must depend on the sort of patient with whom we have to deal. In children, anemic women, and aged persons, it may be admitted rapidly, beginning with the pointer at 1, and proceeding one number at a time every two or three breaths, until the maximum (10) is reached. If any sign of cyanosis, stertor, or twitching of the muscles appear, the oxygen should be increased more rapidly; if, on the other hand, there are symptoms of excitement, crying out, etc., it should be given more slowly or diminished. In dealing with robust, full-blooded patients, caution must be observed in increasing the oxygen, as symptoms of excitement are apt to occur.

The average time required for the induction of anesthesia is, according to Hewitt, one hundred and ten seconds. At the end of that

time, if the case has progressed favorably, the patient should be tranquil, breathing quietly with perhaps slight stertor, the color natural, the pupils contracted, the conjunctiva insensitive, and the muscles relaxed. If the operation be one about the mouth, the face-piece is now removed and the operator proceeds. If the site of operation be away from the mouth, the face-piece can be kept in position and the anesthesia maintained for ten or fifteen minutes very satisfactorily. In these cases it may be found that the patient becomes cyanosed even with the maximum amount of oxygen, and that it is necessary to give an occasional breath of air by raising the face-piece. It has been employed for longer operations of half an hour and more, but in such prolonged administrations it is difficult to maintain a uniform degree of anesthesia and to keep the patient quiet and relaxed throughout; also a good deal of sickness and discomfort is likely to occur after these cases. On the other hand, after short administrations, the patient generally recovers almost as quickly as after nitrous oxid alone, and without disagreeable after-effects. It follows, therefore, that for long operations ether or chloroform is to be preferred.

Administration of Nitrous Oxid and Ether.—It is usual in England to give nitrous oxid as a preliminary to ether. By its use a very speedy induction of anesthesia is attained, with even less probability of struggling and spasm than with ether alone. It is also more agreeable to the patient, who loses consciousness very quickly and does not taste the ether.

Perhaps the most satisfactory of the various forms of apparatus is a

FIG. 187.—Clover's portable regulating ether-inhaler.

Clover's ether-inhaler used in combination with a large bag and stopcock with valves (Fig. 187). The ether-chamber is charged with ether and fitted with a suitable face-piece. The bag is filled with gas from the cylinder, the handle *h* (Fig. 185) shutting off the gas from the stopcock. The distended bag can then be detached from the supply-tube, the gas being prevented from escaping at the lower end by turning the tap *S*.

The amount of gas in the bag is quite sufficient for one administration. The inhaler is applied to the face and the distended gas-bag fitted to it. Air is first freely breathed through the valves. The gas is next put into communication with the inhaler, so that the patient now inspires gas and expires into the air, the valves being in action. The pointer of the inhaler all this time stands at 0. A very few deep breaths are enough to cause unconsciousness, and when about half the gas in the bag has been exhausted, the valves are put out of action by the handle *h*, and the patient now breathes into and out of the bag. The ether is now gradually turned on, though the rotation of the ether-chamber is more rapid than when gas is not used. Thus, ether-vapor is mixed with the gas, and the patient is very soon under its influence. No air should be given until anesthesia is complete, which should be in from two to three minutes from the commencement. The breathing will now be stertorous, and there will be some amount of cyanosis. The large bag is removed at this stage, and the small ether-bag put in its place, air being then admitted for the first time.

Administration of Chloroform.—Chloroform should always be given by the open method—*i. e.*, with a free admixture of air.

One of the simplest and best inhalers is a piece of lint folded on itself so as to make a square piece of double thickness, measuring five or six inches. There are several advantages in this:

1. The evaporation of the vapor is very rapid, and the admixture of air very free.

2. There is little danger of blistering the face, as the lint does not get soaked with the liquid, and is held slightly off the face.

3. It frightens children much less than a more bulky apparatus.

A few drops of chloroform are sprinkled on the lint from a drop bottle, and the lint is at first held at some little distance from the face. Very soon more is added, and this is done at short intervals, before the previous supply has entirely evaporated, each time slightly increasing the dose, and turning the lint with the wet side toward the face. The lint is also brought closer to the face, but without allowing it to touch. The strength of the vapor is thus gradually increased, so that the patient soon becomes accustomed to it without any disagreeable sense of suffocation, and breathes freely. The struggling stage is soon reached, and here great care must be observed, especially if the struggling is violent. If the respiration is free, the administration should be steadily continued by small, frequent, and gradually increasing doses. If any respiratory obstruction occurs, the administration must be withheld till the breathing is free again. This may usually be effected by drawing forward the lower jaw. The pupils at this stage are usually dilated. The patient soon passes into a state of tranquil anesthesia, the muscles are relaxed, the breathing regular, the pupils contracted, and the conjunctiva insensitive. The operation may now be begun.

From this point the anesthesia is to be maintained as far as possible at the same level. The chloroform is no longer increased each time, but small doses are frequently administered. At no time should a large quantity be added, and as the operation proceeds the amount should be decreased gradually, for the longer the anesthesia lasts the less chloroform is required.

A careful watch should be kept on the pupils, which should be maintained at their greatest possible degree of contraction. This is best done by a steady and frequent addition of small quantities of chloroform. If dilatation occurs, it may be either a reflex effect due to insufficient anesthesia or the result of an overdose. In the first case conjunctival reflex will usually be present, in the latter, absent; but if there is any doubt as to the cause of the dilatation, the anesthetic must be withheld till the doubt is removed.

The respiration is to be watched very carefully. If any obstruction occurs, the chin must be drawn forward, or the mouth opened and the tongue drawn out of the mouth. If the respirations become shallow and the face pale, the anesthetic must be stopped, the head lowered, the tongue drawn forward, and, if necessary, artificial respiration performed.

The condition of the pulse must be carefully attended to throughout the administration. Under chloroform there is a liability to depression of the circulation, and any failure of the pulse should be a warning to diminish or discontinue the anesthetic.

During a lengthy operation, if the pulse begins to fail and the patient shows other signs of faintness, it is a good plan either to change to ether, or to mix equal parts of ether and chloroform in the drop-bottle and administer the mixture on lint. The pulse will generally improve under the stimulation of the ether, and the patient be enabled to go through the rest of the operation without further trouble.

In slight degrees of faintness, sharp rubbing of the lips and face with a warm dry towel acts as an excellent stimulant, causing both pulse and color to improve. In cases of serious respiratory or cardiac failure, artificial respiration should be at once resorted to, first seeing that the way is clear for the entrance of air to the lungs. Sylvester's method is the most satisfactory, and should be performed deliberately, the chest being compressed not more than sixteen times in the minute, and sufficient time allowed for its thorough expansion after each compression. Ether may be injected subcutaneously, and heat and electricity applied; but they should not interfere with the artificial respiration, which is by far the most important means of resuscitation.

Chloroform, as has been said before, is borne better, and the danger of cardiac and respiratory failure is much less, if anesthesia has been induced by ether or nitrous oxid and ether. This should always be done if possible, the patient being placed fully under the influence of ether, and thus efficiently stimulated. Children take chloroform well, but are easily overdosed, so great care should be taken to add the anesthetic in very small quantities and to give air freely.

A. C. E. and other Mixtures.—The A. C. E. mixture is administered generally by means of a leather or celluloid inhaler containing a sponge, and having holes in the top for the admission of air. Other mixtures containing a larger proportion of chloroform may be given on lint.

A. C. E. is often used as a preliminary to ether in certain cases, especially alcoholic and fat patients, but it may also be employed during the whole administration. The same precautions must be observed as in the administration of chloroform, especially as to the free admission of air and the addition of small quantities of the anesthetic.

CHAPTER XV.

TUMORS.

THE abnormal conditions to which the term tumor is applied in clinical work may be arranged in four groups: 1. Connective-tissue tumors; 2. Epithelial tumors; 3. Dermoids; 4. Cysts.

Each group contains several genera, and each genus comprises one or more species. The principle of classification (as well as an enumeration of the genera) is described with each group. The definition of each genus and its species is given separately.

Before beginning the systematic description of the various groups, it is necessary to consider some peculiarities relating to the effects of tumors upon the individual, which are of the greatest clinical importance.

In the connective-tissue and the epithelial groups some of the genera display what is known as malignancy; hence it is customary to speak of tumors as being innocent or malignant.

Malignant Tumors.—These exhibit the following characters: 1. They infiltrate the surrounding tissues; 2. They infect adjacent lymph-glands; 3. They tend to recur after removal; 4. They become disseminated in distant organs; and 5. They inevitably destroy life.

Innocent Tumors.—These are, as a rule—1. Encapsuled, and, when diffuse, do not infiltrate; 2. They do not infect the lymph-glands; 3. Nor recur after complete removal; 4. They do not disseminate; and 5. They imperil life only when they grow in the vicinity of vital organs.

There are three genera of tumors to which the adjective malignant is especially applicable—sarcomata, epithelioma, and carcinomata.

It is important to bear in mind that innocent tumors may, and often do, destroy life. The essential difference between an innocent and a malignant tumor may be expressed thus: *The baneful effects of innocent tumors depend entirely on their environment, but malignant tumors destroy life, whatever their situation.*

Environment.—It should be borne in mind that environment exercises an important influence on the rapidity with which a malignant tumor destroys life. It may be useful to describe some examples which will illustrate the importance of environment in relation to the destructive effects of tumors of all kinds.

A tumor consisting of hyaline cartilage (a chondroma) is a typical example of a benign species. The specimen represented in Fig. 188 arose in the submaxillary gland of a woman. When first detected it was as big as a cherry. For many years the tumor grew very slowly and caused little inconvenience. After forty-four years the mass became so cumbrous that she submitted to operation, having attained the age of seventy-four. She happily recovered.

FIG. 188.—Chondroma of the submaxillary gland which had been slowly growing for forty-four years.

FIG. 189.—Chondroma of the lower thoracic vertebræ. An outrunner has crept into the neural canal through an intervertebral foramen (Museum of St. Bartholomew's Hospital, London).

This tumor may be contrasted with the chondroma represented in Fig. 189, growing from the outer surface of a thoracic vertebra and its corresponding rib. An outrunner from the tumor has crept through an intervertebral foramen and spread upward and downward in the neural canal; it compressed the spinal cord, and produced fatal paraplegia.

FIG. 190.—Encapsulated tumor which compressed the trachea and caused death.

The baleful effects of environment are strikingly illustrated in the following case: A man thirty-six years of age was found lying on his back in the street, apparently in a fit, but he quickly died. At the post-mortem examination a tumor no bigger than a dove's egg was found firmly connected with the windpipe; it had so compressed the trachea as to almost obliterate its channel (Fig. 190). Microscopically, the tumor exhibited the character of the thyroid gland. It may have originated in an accessory thyroid or even in a parathyroid.

The preceding examples illustrate the fact that when an innocent tumor causes death, it is an accident depending entirely on its relation to vital organs.

The following illustration demonstrates the dangerous character of a malignant tumor. A man sixty-five years of age had, as long as he could remember, a small black patch 1 cm. (0.4 inch) in diameter on the sole of his foot. Without any obvious reason, this small black area increased, became slightly raised, and began to pulsate. Shortly afterward the lymph-glands in the groin enlarged and formed a big lobulated mass, and in the course of a year the man died with secondary black nodules in the lungs, liver, kidney, spleen, and skin. The urine also contained black pigment (melanin).

It is when tumors arise in a situation such as this, remote from important organs, and yet destroy life in a few months, that malignancy is most significantly expressed.

When a malignant tumor interferes with vital organs, it may cause death very speedily. For instance, the lower half of the esophagus with its gastric orifice, represented in Fig. 191, was removed after death from a man forty-six years of age. He experienced slight irritation in the throat while eating, and this symptom increased so quickly that in five months the communication between the esophagus and the stomach was obstructed, and he died of starvation. The tumor is a carcinoma, shaped like a cotton bobbin. The narrow part of the tumor was gripped by the esophageal opening of the diaphragm, and the broad ends projected, one above and one below this muscle.

One of the most striking facts in connection with malignant tumors is the insidious way in which they will involve organs, and yet give

rise to few signs until they interfere with its function. Many malignant tumors arising in the pelvic organs of men and women run a rapidly fatal course, because they implicate the bladder and the vesical ends of the ureters, and set up renal disturbance and uremia.

It is a marked feature of malignant tumors that when the primary tumor implicates a vital organ, it may destroy life before there has been time for dissemination to occur; when the environment is unfavorable, then death is often induced by secondary nodules occupying important organs, such as the lung, liver, brain, etc.

Innocent tumors differ from malignant ones in the fact that they may occur in multiples. It is common enough to find 5, 10, and even 20 subcutaneous lipomata on an individual. Fifty and even 1000 tumors (fibromata) have been counted on the nerves of one man. Ten or 100 myomata may grow concurrently in a uterus, and 3 or more nevi have often been observed on the skin of an infant. Chondromata, osteomata, and odontomata occur in multiples; while ovarian dermoids and adenomata are frequently bilateral.

Adenomata are often found in both mammæ, and two or three sometimes grow concurrently in the same breast. Multiple adenomata are by no means rare in the thyroid, prostate, and liver. Psammomata, though rare tumors, often occur bilaterally in connection with the choroid plexuses of the brain.

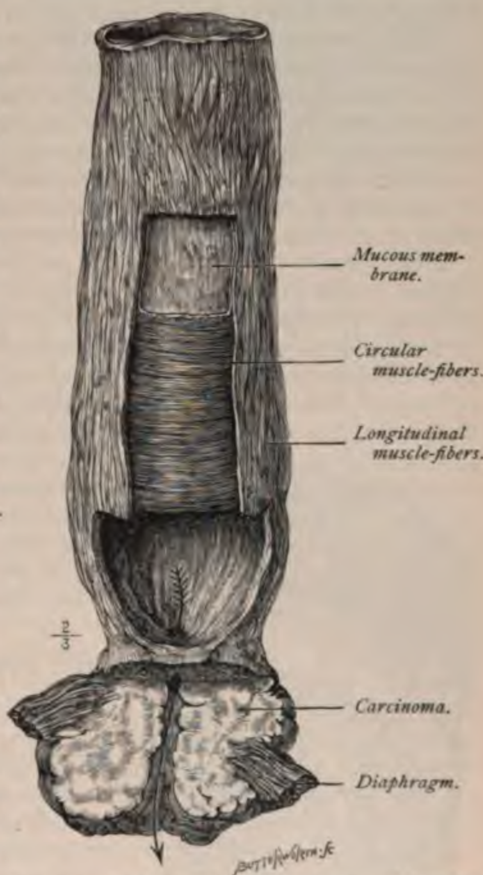

FIG. 191.—Lower half of an esophagus. Its gastric orifice is obstructed by a carcinoma.

It is, however, rare to find two primary sarcomata save in paired organs. Bilateral sarcomata of the kidney, retina, and ovary of infants are common. In one interesting case a kidney of an infant was excised for sarcoma; four and a half years later a sarcoma arose in the remaining kidney and destroyed the patient (Abbe). A similar condition has been observed in connection with the testis. One was removed from a man of seventy years for lymphosarcoma; the disease subsequently arose in the opposite testis and destroyed the patient (Hutchinson).

The occurrence of two primary carcinomata in an individual is exces-

sively rare, except in the peculiar form of skin-cancer known in England as rodent ulcer (see page 488).

The concurrence of primary carcinomata, even in bilateral organs—*e. g.*, the mammæ—has rarely been substantiated by adequate microscopical evidence.

It is excessively rare to find two primary carcinomata of different genera attacking the same person. My own experience is limited to one case. Primary mammary carcinoma occurred in a lady of fifty-eight years; the tumor was removed, and its nature determined by the microscope. Two years later a typical carcinoma arose in the mucous membrane of the rectum; it was successfully excised. Of all the genera of carcinoma, the mammary and uterine are most common, but no instance of their concurrence is recorded.

The coexistence in the same person of two genera of innocent tumors is well known—indeed, is almost a matter of daily observation, uterine myomata and ovarian dermoids, lipomata and sequestration dermoids, chondromata and osteomata, etc., being frequent combinations.

An individual may have one or more innocent tumors for many years, and then a carcinoma may arise, sometimes in an organ already occupied by a tumor. For example, the uterus may be the seat of a large myoma, and carcinoma may subsequently arise in the cervical endometrium.

FIG. 192.—A mamma in section, showing an adenoma (*b*) surrounded by carcinoma (*a*) (Museum of the Royal College of Surgeons, London).

Mammary carcinoma and ovarian adenoma occasionally grow concurrently; or cancer may arise in the mamma a year or more after the removal of a unilateral or bilateral ovarian tumor.

Two examples of the coexistence of pyloric cancer and ovarian adenoma have come under my observation, and on one occasion I removed a myxoma from the lower cervical nerves and a cancerous breast from the same patient on the same day. A very rare combination, observed by Hutchinson, is an adenoma of the mamma embedded in a mammary carcinoma. The woman was forty-six years of age, and had noticed the lump in her breast for twenty years.

An important feature of innocent tumors is the existence in most of them of a distinct capsule which isolates them from the surrounding tissues; those which are "diffuse" differ from malignant tumors in that they do not infiltrate. This distinction between an encapsuled and an infiltrating tumor is shown in Fig. 192; the isolation of the adenoma stands in striking contrast to the indefiniteness of the carcinoma.

The infiltrating propensities of malignant tumors explain in part the frequency and rapidity with which they sometimes recur after removal, for in attempting its extirpation, the surgeon, unable to define their limits, leaves portions of the tumors, and as the life of these outlying fragments is uninfluenced by the removal of the main mass, they continue to grow.

Lymph-gland Infection.—This is a very remarkable feature in connection with epithelioma, carcinomata, and cutaneous melanomata. The cells from the primary tumor are conveyed by the lymphatics to the corresponding lymph-glands, which enlarge and often form masses exceeding in size the primary tumor. When the lymph-glands thus become infected, the removal of the primary tumor in no way influences them, for the carcinomatous elements in the lymph-glands continue to grow and destroy life as surely as if the primary tumor had been allowed to persist.

Dissemination.—The most extraordinary fact in regard to malignant tumors is their tendency to reproduce themselves in distant organs. This dissemination is effected by lymphatics and by veins. The products of this process are known as secondary nodules, and they agree histologically with the primary tumor. In some cases the identity is so complete that an experienced oncologist can often tell from the microscopical structure of a secondary nodule the situation of the primary tumor. Thus, a patient had many secondary nodules in his skin; the primary seat of the disease had not been detected. One of the nodules was excised and found to contain glands such as occur in the stomach and intestine. When the man died, a carcinoma was found at the pyloric end of the stomach.

I. CONNECTIVE-TISSUE TUMORS.

Virchow (1863) demonstrated that all the tissues found in tumors have a physiological prototype, and as complete ignorance exists as to the pathogenesis or cause of tumors, it is necessary for the purpose of classification to use their structural (histologic) characters as a base. Hence it is customary to classify the tumors of this group into genera according to the tissue which preponderates:

1. Lipomata.
2. Chondromata.
3. Osteomata.
4. Odontomata.
5. Fibromata.
6. Myxomata.
7. Gliomata.
8. Neuromata.
9. Angiomata.
10. Lymphangiomata.
11. Myomata.
12. Myelomata.
13. Sarcomata.

Before discussing each genus, it will be useful to point out that Virchow's great generalization has been so well established that if the student were asked to enumerate the primary tumors likely to occur in a particular organ, it would be merely necessary to make a list of the various structures and tissues composing it in order to answer. To put the matter briefly, it may be said that the structure and embryology of an organ are guides to the tumors which may arise therein.

Take, for instance, the tibia of a child of ten years: it contains cartilage, bone, periosteum, fat, and red marrow. Each of these tissues may give rise to a tumor. Thus the epiphyseal cartilage may be the source of a chondroma or an osteoma; the periosteum furnishes sarcomata and occasionally lipomata; and myelomata arise in the red marrow. Epithelial tumors—cancers—do not arise primarily in bone, as it has no epithelium, but they often occur as secondary deposits.

FIG. 193.—Sarcoma of the tibia in a girl, in section.

The doctrine of tissue-prototypes is admirably illustrated in the case of the kidney. This organ is a compound gland consisting of a multitude of complicated (uriniferous) tubules, lined with epithelium. These tubules open into a dilatation (the pelvis) at the upper end of the ureter. The renal pelvis with its recesses (infundibula) consists of unstriped muscle-tissue, lined with epithelium. The sinus of the kidney, besides accommodating the ureter, renal vessels, and nerves, is occupied by connective tissue. In addition, small detached adrenals are occasionally found embedded in the renal cortex immediately beneath the capsule.

Taking our knowledge of the structure of the kidney into account, we should expect to find tumors arising in it which could be accredited to the following genera: Adenoma and carcinoma originating in the cortex; sarcoma growing from the connective tissue of the sinus; myomata starting from the pelvis, and papillomata from its lining epithelium; and, lastly, tumors from the accessory adrenals lodged in its cortex. So far, a true renal adenoma has yet to be demonstrated, but the remaining genera have been repeatedly observed.

Although our knowledge of the intimate structure of tumors, thanks to differential staining methods, is now sufficient to enable us to indicate from the structure of an organ the genera of tumors to which it may be liable, nevertheless the most careful study of the minute structure of such organs as the salivary glands would not lead us to suspect their liability

to pure chondromata; and it is "passing strange" that they should occur in the parotid, submaxillary, and lacrimal glands, and yet be unknown in the pancreas. What oncologist, merely from studying the histology of a normal ovary, would suspect that it would be the point of origin of a dermoid? It is like studying the fauna of a country. For instance, who suspected, until Australia was discovered, the existence of extraordinary mammals like kangaroos and duck moles? But knowledge gained from observation enables us to state that gliomata do not arise in bone, nor myomata in the brain, nor dermoids in the spleen, liver, or kidney, with the same certainty that we assert that at the present period of our planet's history lions do not sport about the ice-fields of Greenland, nor humming-birds flit about the flower-beds of Hyde Park.

It is, however, necessary to point out that, although the tissues of an organ determine the species of tumors to which it may be liable, their relative frequency can be gathered only from observation.

The liability of organs to tumors composed of similar tissues is a very curious matter. The heart is with excessive rarity occupied by a tumor: on the other hand, the uterus, a muscular organ, is with extreme frequency the seat of myomata. The liability of bones to sarcomata is proverbial, yet a sarcoma of a voluntary muscle is a rarity. A primary tumor of the lung is regarded as a phenomenon, but it is common enough in the brain. It is also mysterious why a sarcoma of the shaft of the femur or of the humerus should be the deadliest of all tumors. These and many kindred questions indicate profound imperfection in our knowledge.

Lipomata (*Fatty Tumors*).—These tumors are composed of fat. The genus consists of a single species. They occur in connection with almost every organ of the body.

Subcutaneous Lipomata.—These occur as irregularly lobulated, encapsuled tumors in the subcutaneous fat. They are usually movable within their capsules, and the overlying skin is puckered, especially when an attempt is made to raise it from the underlying tumor.

Lipomata vary in size; some may have a diameter of 2 cm. ($\frac{3}{4}$ inch), whilst others have a circumference of a meter (39.37 in.). In the majority of cases 1 tumor is present; in others 10, 20, or more coexist. The favorite situation is the trunk and trunk-end of the limbs, but they arise on the face, scalp, palm, sole (Fig. 194), fingers, and scrotum. Occasionally they are pedunculated.

There is a variety, most frequently seen on the arms and thighs, occasionally on the trunk, and rarely exceeding the dimensions of a filbert nut, which occurs in multiples, and, as they are often painful, simulate neuromata. Irregular non-encapsuled masses of fat are sometimes seen on the neck, axillæ, and groins; they are known as "diffuse lipomata." Fatty tumors that have existed many years sometimes calcify, the earthy salts being deposited in the fibrous septa of the tumor. This change may affect pedunculated as well as sessile lipomata; saponification occasionally occurs in old lipomata.

Very vascular lipomata are sometimes called nevolipomata: they are met with on the face and on the periosteum of long bones in situations where it is subcutaneous.

Subserous Lipomata.—The peritoneum, like the skin, rests upon a bed of fat. Lipomata of enormous dimensions arise sometimes in this subserous layer, and, like the subcutaneous species, they may be sessile or pedunculated. Fatty tumors sometimes arise in the reduplications of the peritoneum, such as the omentum, mesentery, and mesometrium. When they drag upon the peritoneum in the neighborhood of the inguinal rings, the crural canal, or adventitious opening in the linea alba or diaphragm, they produce finger-like pouches known as fatty herniæ. These are especially common in the neighborhood of the umbilicus. Pedunculated subserous lipomata are usually associ-

FIG. 194.—Lipoma of the sole which had existed for thirty years. It was removed by Percival Pott (Museum of St. Bartholomew's Hospital, London).

ated with the colon; they are usually exaggerated epiploic appendages. This species of lipomata sometimes arises in the spermatic cord, and assumes a characteristic elongated, ovoid shape.

Subsynovial Lipomata.—Many synovial membranes have fat in their deeper layers. This may project into the joint, and, becoming pedunculated, form subsynovial lipomata. Usually many—50 to 100—are present. Müller termed the condition "lipoma arborescens."

Submucous lipomata rarely attain a large size. They have been found in the conjunctiva, lips, pharynx, larynx, stomach, small intestine, colon, and rectum. They may be sessile or stalked.

Intermuscular Lipomata.—The connective tissue of intermuscular septa is provided with fat and is the source of fatty tumors, sometimes of large size. They occur equally in the trunk and limbs.

Intramuscular Lipomata.—Many examples of fatty tumors occurring in muscles have been recorded. They have been found in the

biceps, deltoid, complexus, the cardiac septum, and the rectus abdominis.

Periosteal lipomata arise from the periosteum of bones, and nearly always contain tracts of striped muscle-tissue. They have been observed on the scapula, innominate bone, clavicle, humerus, radius, ulna, femur, tibia, fibula, cervical vertebræ, and the frontal bone, and they often simulate periosteal sarcomata.

Meningeal Lipomata.—Fatty tumors occur on the outer or inner surface of the spinal dura mater. The extradural variety often overlies the sac of a spina bifida. Intradural lipomata may contain tracts of striped muscle-tissue; occasionally they are associated with a masked spina bifida. Fatty tumors growing from the sheath of nerves are sometimes called neurolipomata.

Chrondomata (*Cartilage Tumors*).—These tumors are composed of hyaline cartilage. The genus contains three species: 1. Chondromata; 2. Ecchondroses; 3. Loose cartilages in joints.

Chondromata.—In the most typical condition this species is met with in the long bones of the limbs, especially those of the hand. They arise in connection with epiphyseal cartilages; hence chondromata are more common in children and in early adult life. They often occur in multiples, but solitary examples are not rare. Those who have had rickets are especially prone to develop chondromata, and the tumor-tissue resembles the bluish, translucent cartilage so characteristic of the rickety epiphyseal line. Chondromata are encapsuled, painless, grow slowly, and are very prone to mucoid degeneration; they frequently ossify. Tumors composed of pure hyaline cartilage occur in the parotid, submaxillary, and lacrimal glands. (See *Chondrifying Sarcoma*, page 477.)

Ecchondroses are local outgrowths of cartilages, and occur along the edges of articular cartilages, especially of the knee-joint. They are common on the triangular cartilage of the nose, and occasionally spring from the cartilages of the larynx.

Loose Cartilages of Joints.—The pedunculated fringes hanging from the synovial membranes of joints often chondrify, and, when they become detached, give rise to one variety of loose body in the joint.

Osteomata (*Bony Tumors*).—An osteoma may be defined as an ossifying chondroma. The genus contains two species: 1. Compact or ivory osteoma; 2. Cancellous osteoma.

Compact osteomata are structurally identical with the compact tissue of the shaft of a long bone. Often their substance is as dense as that of the petrosal. They occur most frequently on the bones of the skull, especially from the walls of the frontal sinus, the osseous walls of the external auditory meatus, the mastoid process, and the angle of the mandible. This species is usually sessile.

Cancellous osteomata resemble in structure the cancellous tissue of bone. They usually arise in the neighborhood of the epiphyseal lines, and, when growing, are capped with cartilage, which bears the same relation to the tumor that an epiphyseal line bears to a long bone. These tumors may be sessile or pedunculated. When situated at the distal end of the radius or tibia, they are deeply channelled by the flexor and extensor tendons. When projecting near the skin, the summit is

often surmounted by a bursa. This species may be single; often they are multiple.

Exostoses.—Often all bony outgrowths, including osteomata, are vaguely classed as exostoses. Under the term exostosis are included ossification of tendons at their attachments, the subungual exostosis, and calcified inflammatory exudations. An exostosis is not a true tumor.

Odontomes (*Tooth Tumors*).—These are tumors composed of dental tissues in varying proportions and different degrees of development, arising from teeth-germs or teeth still in the process of growth. The species, determined according to the part of the tooth-germ concerned in their formation, are: 1. Epithelial odontome; 2. Follicular odontome; 3. Fibrous odontome; 4. Cementome; 5. Compound follicular odontome; 6. Radicular odontome; 7. Composite odontome.

Epithelial odontomes arise from the enamel organ, and occur as encapsuled tumors in the jaws. On section they are made up of congeries of cysts of various shapes and sizes. Histologically they consist of branching and anastomosing columns of epithelium which contain tissue resembling the stratum intermedium of an enamel organ.

Follicular Odontomes (*Dentigerous Cyst* of older writers).—This species is usually associated with the permanent teeth. They arise in this way: A tooth is retained, and the wall of the follicle becomes greatly thickened and distended with fluid. The tooth may be loose in the sac, sometimes inverted, or its root may be truncated (incomplete). As a rule, a single odontome is present, but 2 and even 4 may coexist.

Fibrous Odontomes.—Every tooth before eruption is enclosed in a fibrous capsule—the tooth-sac. This sac may become so thick that the tooth is embedded and remains non-erupted. Sometimes it is represented as a denticle. This species has often been described as myeloid sarcoma. It occurs most frequently in rickety children.

Cementomes are met with in ruminants; they are rarely observed in man.

Compound follicular odontomes consist of fibrous tumors with numerous denticles embedded in their substance, which erupt from time to time.

Radicular odontomes arise after the crown of the tooth is completed, and are formed from the tooth-papilla. They consist of dentine and cementum in varying proportions.

Composite odontomes are due to disorder of the whole tooth-germ; they consist of enamel, dentine, and cementum irregularly intermixed.

Odontomes occur in the upper as well as the lower jaw; but all the species attain a far larger size in the maxilla than in the mandible, for they are able to invade the antrum, and for a time there is less restriction to their growth.

Fibromata.—These are tumors composed of fibrous tissue. This genus contains two species—simple fibroma and molluscum fibrosum.

Simple Fibroma.—Tumors of this species are composed of wavy bundles of dense fibrous tissue. The bundles consist of long, slender, fusiform cells, closely packed together and frequently arranged in whorls; the arteries of the tumor frequently traverse the centers of

the vortices. Simple fibromata occur in the following situations: On the gums (epulis), in the ovary, uterus (fibroids), on nerves (neuromata), and as the tiny nodules in the skin known as painful subcutaneous tubercle. It is a matter of great difficulty to determine histologically between some fibromata and slowly-growing, spindle-celled sarcomata.

Molluscum Fibrosum.—This extraordinary condition of the skin has been described under a variety of names—dermatolysis, fibrocellular tumor, etc. It consists of overgrowth of skin and subcutaneous tissue, which may affect a small area like the scalp, or involve a large extent of skin on the trunk or limbs, causing it to hang in pendulous folds. Occasionally a solitary molluscum nodule may hang by means of a cylindrical stalk from the greater labium, or even from the nipple

FIG. 195.—Pedunculated molluscum fibrosum which grew from the mammary areola (Museum of Middlesex Hospital, London).

or mammary areola (Fig. 195). Sometimes it assumes the form of discrete nodules scattered about the skin, the nodules varying in size from a pea to a walnut. Cutaneous nodules and pendulous skin-folds occur in the same individual, and occasionally multiple nodules in the skin are associated with a multitude of fibrous nodules on the trunks of the peripheral nerves (multiple neuromata).

Simple fibromata and the molluscum fibrosum, whether they occur as a pendulous fold or as a discrete nodule, show no disposition to recur after removal, and are not very vascular.

Myxomata.—These tumors are composed of tissue identical with that which surrounds the vessels of the umbilical cord.

The genus contains a single species—myxoma. Tumors composed almost entirely of myxomatous tissue are very rare, and, when cut into, resemble a mass of trembling jelly, from which a quantity of straw-colored fluid drains away. Microscopically, myxomatous tissue consists of cells with long, slender, delicate processes.

Myxomata are very rare, but many tumors contain tracts of myxomatous tissue as a secondary change. This is especially the case with

chondromata, fibromata, myomata, and sarcomata. The characters of myxomata may be studied in the common nasal polypi. These are edematous pendulous processes of mucous membrane.

Gliomata.—The tumors of this genus are composed of the delicate connective tissue known as neuroglia. It contains a single species—glioma.

Gliomata occur only in the central nervous system as tumors imperfectly demarcated from the surrounding tissue. A glioma may consist of translucent tissue of the consistence of vitreous humor, or it may be as firm as the cerebral cortex. The tumors consist of cells furnished with delicate ramifying processes: the cells contain one or more nuclei. Gliomata are quite often very vascular, and in some the vessels are so numerous that they have been described as cerebral angiomata or angiosarcomata.

Gliomata are, as a rule, solitary tumors, and do not disseminate. They are twenty times more common in the brain than in the spinal cord.

Neuromata.—It is desirable to discard this term, because it is used in clinical work as signifying a tumor of a nerve. As tumors of nerves may be fibromata, myxomata, lipomata, or sarcomata, it is far better to speak of them as fibroma of a nerve, lipoma of a nerve, and so forth.

Nerves are liable to a singular condition which it is found convenient to term *plexiform neuroma*, in which the nerves distributed to or lying in relation with the subcutaneous tissue of a brown mother-mark or a hairy mole become greatly thickened, tortuous, and sometimes almost translucent, due to the large amount of myxomatous tissue in the nerve-sheath. This curious but rare condition may occasionally occur independently of a mole. Plexiform neuromata have a distribution as wide as that of hairy moles; they occur on the hairy scalp as well as on the less hairy regions of the skin. The strange occasional association of molluscum nodules and pendulous molluscum folds with fibromata of nerves has already been alluded to (page 469).

Angiomata.—These are tumors composed of an abnormal formation of blood-vessels. The genus contains three species—simple nevus; cavernous nevus; plexiform angioma.

Simple Nevus.—Of this species there are three varieties. A nevus may appear as a superficial pink or deep-blue discoloration of the skin, known as "port-wine stain;" it may involve an area of skin 2 cm. ($\frac{3}{4}$ inch) square, or a large part of the face, half the trunk, or even a whole limb.

More frequently the nevus appears in the form termed telangiectasis. This consists of an abnormal collection of arterioles or venules in the skin, the subcutaneous and subperitoneal tissue, less frequently in mucous membrane. All examples of telangiectasis contain arterioles, venules, lymphatics, and fat in varying proportions. When arterioles preponderate, the nevus is red; when venules are in excess, it is blue; when lymphatics are most numerous, it may be light pink or nearly colorless; this is a lymphangioma (see page 471). Some venous nevi are encapsuled, and simulate dermoids and cystic tumors. Many encapsuled nevi contain a large proportion of fat, and are then termed *nevolipomata*.

Cavernous Nevi.—These are in structure like the vascular portions of the corpus cavernosum and corpus spongiosum, and are made up of venous and arterial channels and sinuses communicating with neighboring arteries and veins. A cavernous nevus sometimes arises from the transformation of a telangiectasis. This species of nevus is red or blue, according to the predominance of arterial or venous channels.

Cavernous nevi, like simple ones, as a rule, are either congenital or appear in early infancy. Many nevi disappear; others when first seen are small and inconspicuous, then rapidly grow, and in a few months form conspicuous tumors. Cavernous nevi have the same distribution as the simple species. Cavernous nevi, like the telangiectactic variety, have been met with in the subperitoneal tissue, and especially in connection with the serous surface of the liver. The central parts of a large cavernous nevus sometimes degenerate and are occupied by loculi filled with lymph.

Plexiform Angioma.—This species consists of a number of blood-vessels arranged more or less parallel with each other. Many pursue a tortuous course. In some tumors arteries alone are present, in others there are veins and arteries. Plexiform angiomata are rare; they occur most commonly on the scalp and upper limb. Plexiform angiomata have a physiological prototype in the retia mirabilia, which occur naturally in the intercostal spaces of whales, the tails of ant-eaters, and the forearms of the sloth and some species of lemurs.

Lymphangiomata.—These tumors are composed of an abnormal formation of lymphatics. A lymphangioma has the same relation to lymphatics that an angioma bears to blood-vessels.

The genus contains three species—lymphatic nevus; cavernous lymphangioma; lymphatic cysts.

Lymphatic Nevus.—These are, as a rule, colorless, but when a few hemic capillaries are present, they possess a light pink tint and are slightly raised above the surrounding skin. When arising on the skin, they rarely exceed 2 cm. ($\frac{3}{4}$ inch) in diameter. The most striking example of lymphangioma occurs in the mucous membrane of the tongue, and may cause such enlargement of this organ that it protrudes from the mouth. The condition is clinically known as macroglossia.

Cavernous lymphangioma resembles in structure a cavernous angioma, except that the spaces are filled with lymph instead of blood. They are rare tumors.

Lymphatic cysts appear as congenital cysts in the neck, axilla, and adjacent part of the thoracic wall. Those which arise in the posterior triangle are sometimes termed "hydrocele of the neck." Lymphatic cysts are easily recognizable; they are always noticed at or immediately after birth, and are sometimes of very large size (Fig. 196). The walls of such a cyst are very thin, and the tumor is often translucent like a hydrocele of the tunica vaginalis testis. The cysts occur, as a rule, on one side, though sometimes they are bilateral. Each may contain a single chamber or be made up of a number of intercommunicating loculi filled with lymph. Some of them resemble the large subcutaneous lymph-spaces of frogs.

It is a remarkable fact that many of these cysts shrivel and disappear. They are exceptionally liable to inflame, and several cases have

been recorded in which they have been burst by the patient falling upon them. Their proneness to spontaneous cure explains their rarity after puberty. The spontaneous effacement of these cysts is preceded by a sudden increase in their size; they become hot, tender, and inflame; as these signs subside, the cyst slowly disappears.

FIG. 196.—Lymphatic cyst in the neck of an infant.

Myomata.—These are composed of unstriped muscle-fiber. The genus contains one species—myoma.

Myomata arise in organs containing unstriped muscle-tissue, such as the uterus, bladder, esophagus, stomach, and intestine. They have been found in the dartoid tissue of the scrotum. Occasionally they arise in the mesometrium, Fallopian tube, ovary, and ovarian ligament.

The most characteristic myomata arise in the uterus as encapsuled tumors; even when pedunculated they possess a distinct capsule. The muscle-cells are fusiform in shape and possess a rod-like nucleus; the bundles of fibers are often interwoven and produce characteristic whorls. Uterine myomata arise during the sexual period of life, and are most frequent between the thirtieth and forty-fifth years. They are rarely single, and 100 may sometimes be counted in one uterus. They vary greatly in the rate of growth; those which grow slowly are, as a rule, very hard, and contain much fibrous tissue. Soft myomata grow rapidly, are very vascular, and sometimes weigh as much as 30 or even 50 pounds. Vascular, soft, and rapidly growing specimens often furnish a loud systolic murmur. They are liable to secondary changes: thus, hard myomata calcify, softer specimens undergo myxomatous degeneration, and large tracts of tissue assume the consistency of honey; fatty changes are rare, and lardaceous degeneration still rarer. When the tumors are extruded into the vagina, they are liable to become infected, and then they inflame and become gangrenous.

A myoma of the uterus may endanger life by frequent hemorrhage, by pressure on the urethra and ureters, inducing renal disturbance, especially when it grows from the cervix, and by sepsis when an intra-uterine polypus becomes infected (Fig. 197). A myoma impacted on

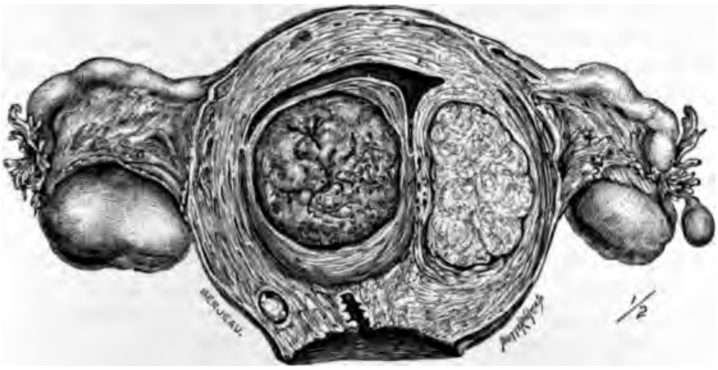

FIG. 197.—Myomata of the body of the uterus. The capsule of one has been opened by ulceration.

the pelvis may cause fatal intestinal obstruction, and a pedunculated subserous tumor may entangle a loop of bowel. When pregnancy occurs in association with myomata, the complication seriously interferes with the growth and life of the fetus, and often gravely imperils the life of the mother.

A cervix myoma particularly menaces life, as it rarely gives rise to symptoms until it has occupied the available space in the true pelvis. It then compresses the urethra and leads to retention of urine. Myomata of the cervix are ovoid in shape and furnish a characteristic elliptical section.

A myoma growing from the intestinal wall and projecting into the gut may lead to intussusception, and a small myoma projecting into the uterine cavity sometimes leads to inversion.

Myelomata.—These tumors, formerly called myeloid sarcomata, are composed of tissue identical with the red marrow of young bone. The genus contains a single species—myeloma. The cut surface of the tumor is deep red, not unlike a piece of liver, and is very vascular. Microscopically, a myeloma abounds in multinuclear cells embedded in round or spindle cells. The giant cells are so numerous as to constitute the greater proportion of the tumor. These tumors occur most frequently at the ends of long bones; the upper end of the tibia and the lower end of the radius (Fig.

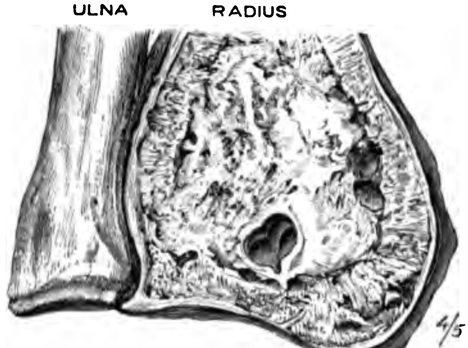

FIG. 198.—Myeloma of the lower end of the radius (Museum of St. Thomas's Hospital, London).

198) are the common situations. In the cranial bones they are confined to the maxilla and mandible.

The patients are young, rarely above twenty-five years. The tumor grows slowly, expands the bone equally, and thins the osseous capsule, while expanding it, until the bony shell is so thin as to crepitate when pressed by the finger. Here and there the marrow-tissue perforates the capsule, and markedly pulsates synchronously with the cardiac systole.

Myelomata do not infect lymph-glands and do not disseminate; if the patients come under observation before the tumor has perforated its capsule, it may be thoroughly extirpated without fear of recurrence. The manner of effecting "thorough extirpation" varies with the situation of the tumor.

Sarcomata.—These tumors are composed of tissues resembling immature connective tissue, in which cells preponderate over the intercellular substance. The genus contains five species, which are determined according to the shape and disposition of the cells—round-celled sarcoma; lymphosarcoma; spindle-celled sarcoma; alveolar sarcoma; melanosarcoma.

Round-celled Sarcoma.—In this species the cells are round, and there is very little intercellular substance. Each cell has a large, round, vesicular nucleus and a small proportion of protoplasm. Blood-vessels are very abundant; lymphatics absent. These tumors infiltrate, disseminate, and recur after removal. Round-celled sarcomata are the most generalized and the most deadly tumors which affect mankind. They occur in any organ—bone, brain, muscle, spinal cord, ovary, testis, and even in the delicate tissues of the eye. They occur at any age, from the fetus in the uterus up to the extreme age-limit of human life. There is abundant reason for the belief that many supposed examples of round-celled sarcoma are really granulomata, especially large syphilitic gummata.

Lymphosarcoma.—In this species the tumor-tissue resembles that of a lymphatic gland. These tumors must not be confounded with simple enlargement of a lymph-gland, or the general increase of lymphadenoid tissue associated with leukemia or lymphadenoma (Hodgkin's disease).

Lymphosarcoma not only possesses a definite structure, but occurs in definite situations, such as the superior mediastinum, the subpleural and subperitoneal tissues, the base of the tongue, the larynx, the tonsils, and the testes. Like the small round-celled sarcomata, they are infiltrating and deadly tumors, but they have a more limited age-distribution, occuring most frequently in young adults.

Spindle-celled Sarcomata.—In this species the cells, though they vary greatly in size, agree in the circumstance that they are oat-shaped or fusiform. The cells have a tendency to run in bundles, which take different directions, so that in sections of the tumor seen under the microscope some cells will be cut in the direction of their length and others at right angles. In some tumors the cells are so thin and slender and contain so little protoplasm that they seem to consist only of a nucleus and cell-processes. It is difficult to distinguish such tissue from moderately firm fibrous tissue. In other specimens the cells are large, beautifully fusiform, and rich in protoplasm; some of these cells are transversely striated like voluntary muscle-fiber (Fig. 199).

Spindle-celled sarcomata often contain tracts of immature hyaline cartilage, fibrous tissue, and spicules of bone. Multinuclear (giant) cells are usually present. When particular tissues are abundant in spindle-celled tumors, they sometimes receive distinguishing names, such as chondrosarcoma, fibrosarcoma, myosarcoma, etc.

Spindle-celled sarcomata arise especially in periosteum and secreting glands, such as the ovary, testis, parotid, kidney, and the mamma.

Alveolar Sarcoma.—This species differs in an important manner from sarcomata in general, for the cells assume an alveolar disposition, and on section resemble the carcinomata. There is, however, this great difference—they do not originate in, or reproduce, the structure of secreting glands. This species illustrates very well the way in which the structure of tumors depends on the tissue in which they

FIG. 199.—Cells from a spindle-celled sarcoma of the neck of the uterus. Some of the cells present a cross striation (Pernice).

arise. Alveolar sarcomata originate almost exclusively in the skin, and especially in relation with those congenital defects known as hairy and pigmented moles. The tissue forming the base of moles has the peculiar alveolar disposition which serves as the histologic type of this species of sarcoma.

Melanosarcomata.—This species is distinguished by the presence of black pigment (melanin) in the cells and intracellular substance. The cells composing melanosarcoma may be round or spindle-shaped; in many they are collected in alveoli.

The amount of pigment varies. In some merely a brown discoloration is produced; in others the tumor is of a deep sepia color. It is also a curious fact that the primary tumor may contain very little pigment, and the secondary deposits be of a deep black color.

Melanosarcomata arise in the skin and in the uveal tract. Cutaneous melanosarcomata arise in connection with pigmented and hairy moles, in the vulva, the anus, and the nail-matrices of fingers and toes. As a rule, they infect the nearest lymph-glands, disseminate very rapidly,

and recur very quickly if removed. In some cases the tumor seems to be mainly a source of pigment, large quantities of which enter the circulation, to be discharged in the urine as melanin. Intra-ocular melanomata may arise from any part of the uveal tract. They are ten times more common in the choroid than in the ciliary body, and are excessively rare in the iris. Melanomata of the ciliary body often exhibit the structure of carcinoma. Intra-ocular melanomata have been observed as early as the fifteenth and as late as the eightieth year; the greater number occur between fifty and sixty. Death more often results from the secondary deposits than from the local effects of the primary tumor.

The General Characters of Sarcomata.—All the species of this genus are very vascular, but the circulation within the tumor is mainly capillary; in those which grow rapidly the vessels are so numerous as to produce a visible pulsation and an audible "hum." The force of the circulation is often sufficient to rupture the capillary channels and convert the central parts of the tumor into a blood-containing cavity. This intimate relation of sarcomata to the blood-vessels favors dissemination. On examining the veins leading from the tumor, processes from the sarcoma will be found extending into their lumina, and minute portions, becoming dislodged, are conveyed to the right side of the heart, and on entering the pulmonary circulation they are arrested in the lung-tissue, and engraft themselves to form secondary deposits. When the primary tumor occurs in the vicinity of the portal circulation, the secondary nodules will be most abundant in the liver. Occasionally a large vein like the renal, iliac, or even the vena cava will be blocked by sarcomatous outrunners, and fragments become detached of a size sufficient to block the pulmonary artery, or even the right auriculoventricular orifice. Secondary nodules occur in other situations than the lungs and liver, for in some of the round-celled tumors nodules amounting to many hundred may appear in almost every organ of the body.

The facility with which sarcomata gain entrance to veins is due to their extraordinary infiltrating properties. In some instances, and in the early stages of many, sarcomata are encapsuled, but the majority lack a capsule and grow in every direction. Thus, a sarcoma of a bone will send outrunners along the Haversian canals; in the skull, portions will creep into the foramina and recesses; a sarcoma of a voluntary muscle will invade its constituent bundles and even separate its ultimate fasciculi. Yet this infiltrating tendency is easily restrained in the early stages. For instance, a sarcoma of muscle is easily retained within the sheath, and a sarcoma of the spermatic cord will quickly occupy the cord and become moulded by its outer tunics (Fig. 200). This is also true of subperiosteal sarcomata.

Sarcomata are devoid of lymphatics; hence the adjacent lymph-glands are not, as a rule, infected. Should the sarcoma implicate the overlying skin or mucous membrane and ulcerate, then the lymph-glands will enlarge.

Sarcomata are very liable to degenerative changes. It has already been mentioned that extravasations of blood will produce spurious cysts, and a like effect follows necrosis of considerable portions of the

tumor. Myxomatous change will often cause liquefaction and form a cavity in a large tumor, big enough to accommodate the fist. Calcification and ossification are frequent changes in sarcomata growing from periosteum, and produce abundant arborescent processes and spicules (Fig. 201). When the sarcoma arises in the central parts of a long bone and grows slowly, it will expand the surrounding osseous tissue (Fig. 202).

In slow-growing sarcomata of the spindle-celled species tracts of

FIG. 200.—Round-celled sarcoma of the spermatic cord.

FIG. 201.—Skeleton of a periosteal sarcoma of the scapula (Museum of St. Thomas's Hospital, London).

hyaline cartilage are often found. Such are sometimes called *chondro-sarcomata*.

Distribution.—Sarcomata arise from connective tissue, and although this tissue occurs in every part of the body, they are far commoner in some situations than in others. Thus they are frequent in subcutaneous tissue, fascia, intermuscular septa, and the periosteum. They are rare as primary tumors of muscle-tissue, striped or unstriped. Even when hollow muscles, like the bladder, intestine, and uterus, are the seat of sarcomata, they originate in the mucous membrane; and, most

striking of all, a sarcoma of the heart is unknown. Even the delicate connective tissue of the retina, the uveal tract, the neuroglia of the brain and spinal cord, and the sheaths of the nerves are attacked by these deadly tumors.

In considering the distribution of sarcomata, it is necessary to make special mention of their occurrence in secreting glands. All compound glands, such as the kidney, testis, parotid, prostate, mamma, etc., contain a fair amount of connective tissue, and it would naturally come about that a sarcoma arising in this tissue would tend to entangle the gland-acini in its substance. Thus, in the kidney uriniferous tubules would be expected. Follicles occur in an ovarian sarcoma, and galactophorous ducts and glands in a mammary sarcoma. These are often termed adenosarcomata, a term apt to mislead.

FIG. 202.—Shaft of a tibia expanded by a central tumor (Museum of the Royal College of Surgeons, London).

A very striking fact in connection with sarcomata arising in secreting glands is the frequent occurrence of hyaline cartilage, and in some—*e. g.*, the kidney and testis—striped muscle-fiber. When striped spindle-cells are present, the tumor is sometimes called a myosarcoma.

It is a fact of considerable interest that sarcomata are especially rare in the liver, the thyroid, pancreas, and lungs; and, as showing that their structure is modified by the nature of the connective tissue in which they arise, reference need only be made to those originating in the retina, to alveolar sarcoma of pigmented moles, and sarcoma (deciduoma) arising in a gravid or recently gravid uterus. Age modifies the liability to, as well as the structure of, sarcomata in some glands. Thus, retinal sarcomata are common in infants, bilateral in nearly half the cases, and are unknown

after twelve years of age. Intra-ocular melanomata are unknown before puberty, and are unilateral. Sarcomata of the ovaries are more common before puberty than in later life, and are often bilateral; in adults they are usually unilateral.

Adrenal Tumors (*Suprarenal Capsule*).—The species of this genus are very remarkable tumors, and until our knowledge of them is more

FIG. 203.—Sarcoma of the kidney of an infant, arising from the connective tissue in the renal sinus.

extensive and precise, it will be judicious to let them rank among the sarcomata.

Tumors arising in and reproducing the peculiar structure of the adrenal have been many times recorded. Tumor-like bilateral enlargement of the adrenals has been observed in children, whereas in adults the enlargement affects one adrenal, and may attain the dimensions of a melon. In some instances there have been secondary deposits in the viscera, especially the liver. It is a remarkable fact that tumors sometimes of large size and histologically identical with the zona fasciculata arise in accessory adrenals. These bodies are fairly frequent; they occur in the capsule of the liver and between the layers of its falciform ligament; also beneath the capsule of the kidney (Fig. 203), and in the course of the spermatic artery. Less frequently they have been detected in the anterior layer of the mesometrium of the fetus at term and in early infancy.

Tumors supposed to arise in accessory adrenals situated in the kidney are very important. They occur as encapsuled masses in the cortex, and rarely communicate with the renal pelvis; hence, hematuria is not so constant as in sarcomata springing from the connective tissue in the sinus of the kidney. A striking feature of these tumors is their delicate structure and the frequency with which blood-extravasations take place in them, whereby the central parts are often transformed into cyst-like spaces filled with blood-coagulum (Fig. 204). This liability to hemorrhage is also a common feature of these tumors when arising in the adrenal itself. The majority of the specimens on

record were observed in men and women between the fortieth and fifty-fifth years of life. Tumors of the adrenals and tumors that arise in accessory adrenals simulate each other during life so closely that it

FIG. 204.—Adrenal tumor of the kidney. This tumor in structure resembled the adrenal at the third month of intra-uterine life.

is as yet impossible to differentiate them by clinical methods or to distinguish them from other species of renal tumors.

II. EPITHELIAL TUMORS.

In this group of tumors the presence of epithelium and its mode of distribution are the essential and distinguishing features. In the bodies of animals epithelium is disposed in various ways and serves various functions. In many situations where it is protective it is arranged in layers (stratified); in others it is modified to form hair, feather, bristles, nail, or horn; in others it dips into the underlying tissues to form secreting organs (glands), some of which are very simple, as in the intestine, or exceedingly complex, as in the liver, kidney, or testis. Whether a gland is simple or complex, the principle of construction is identical—namely, narrow channels lined with epithelium resting upon a connective-tissue base, in which blood-vessels, lymphatics, and nerves ramify. The recesses of glands communicate, either directly or by means of a duct, with a free surface. To this rule

there are three exceptions—the thyroid gland, the pituitary body, and the ovary.

The variations in the disposition of epithelium enable epithelial tumors to be arranged in four genera: Papilloma; epithelioma; adenoma; carcinoma.

Papilloma (*Warts*).—A wart consists of an axis of fibrous tissue containing blood-vessels, surmounted by epithelium. It may be simple, or covered with secondary processes and resemble a mulberry.

This genus contains four species: 1. Warts; 2. Villous papillomata; 3. Intracystic warts; 4. Psammomata.

Warts.—These occur in the skin, singly or in multitudes. They are rarely painful, unless irritated. In adults they are common on the glans penis and prepuce, and on the vulva and surrounding skin, as the result of irritating urethral, preputial, and vaginal discharges. Warts arise on the laryngeal mucous membrane, especially of children. Large solitary warts often contain pigment, and later in life are liable to be the starting point of a melanoma. The thick layers of epithelium on large warts sometimes decompose (ulcerate) and become horribly offensive. Occasionally the surface-cells become keratinized and form horn. Epithelioma sometimes arises at the base of a large solitary wart, especially if the wart has been irritated.

The crops of warts which occur on the hands of children never lead to serious consequences, and, as a rule, disappear spontaneously, sometimes as if by magic.

Villous Papillomata.—This species consists of feather-like tufts resembling chorionic villi. Each villus consists of a delicate axis of connective tissue, containing delicate loops of blood-vessels and surmounted by epithelium. The villi may be simple or compound. Thus, in structure they resemble chorionic villi.

The villous papilloma grows from the mucous membrane of the bladder, and occasionally from the pelvis of the kidney. Cases are known in which villous papillomata of the renal pelvis have been associated with villous tufts in the bladder, around the orifices of the ureters, probably due to the grafting of epithelium derived from the villi in the kidney or the vesical mucous membrane. An interesting variety of villous papilloma arises from the choroid plexuses of the cerebral ventricles; when large and situated in the fourth ventricle, they have produced death from pressure. Villous papillomata of the choroid plexuses rarely attain a large size without undergoing calcification (see *Psammoma*). Renal and vesical villous papillomata give rise to oft-recurring bleeding, and sometimes cause death.

Intracystic Papillomata.—Warts may arise from any epithelial surface, and as all true cysts are lined with epithelium, they are liable to warts. Intracystic warts occur in the following situations—in cysts of the mammary glands; cysts of the paroöphoron, parovarium, and Gärtner's duct; and cysts arising in accessory thyroid glands.

It should be remembered that many intracystic growths are structurally adenomata, and in the case of mammary cysts it is difficult to decide the nature of the intracystic process without the aid of the microscope.

The example represented in Fig. 205 shows a cyst formed by the

dilatation of a galactophorous sinus, and in this instance the knob-like process is composed of villi. In such a case it is easy to trace the duct belonging to the sinus into the cyst, and it is often possible during life to squeeze fluid from the cyst and make it appear at the nipple. In some cases the patients are much inconvenienced by the involuntary escape of blood-stained fluid from the nipple, often in quantity sufficient to soak their linen.

FIG. 205.—Warts in a cyst formed by a dilated galactophorous sinus.

Psammomata.—These tumors are composed of globular bodies consisting of epithelium arranged in layers, usually calcified and embedded in connective tissue. The amount of calcareous matter they contain is very variable; sometimes they are of stony hardness. Psammomata occur exclusively in connection with the pia mater of the brain and spinal cord. They are particularly liable to grow from the choroid plexuses of the ventricles. A very favorite situation is the tufts of villi which protrude from the lateral recesses of the fourth ventricle. Psammomata arising from the choroid plexuses of the lateral and the fourth ventricle are often bilateral. In the latter situation they exert injurious pressure on the facial, trigeminal, and auditory nerves.

A psammoma arising in connection with the spinal membranes leads to far more serious results than a tumor of the same size arising in the lateral ventricles. It is a curious fact that there is singular uniformity in the size and shape of psammomata observed in the spinal canal. They lead to slow, progressive paralysis and death.

Horns.—There are four varieties of these curious structures—sebaceous horns; wart horns; cicatrix horns; nail horns.

Sebaceous horns may arise in any situation where sebaceous glands exist. They are formed from the epithelium of the gland, and sometimes attain a length of many centimeters. The horns are tough and present a longitudinal fibrillation; when soaked in a weak solution of liquor potassæ, the tissue softens and falls away in flakes.

Wart horns are identical in appearance with sebaceous horns, and the only means of deciding between them is to split the horns longitudinally and ascertain whether the base is occupied by a wart or a sebaceous cyst.

Sebaceous horns are common on the scalp, and wart horns are most frequent on the glans penis near the corona.

Cicatrix horns are rare; they occur chiefly in the scar left by burns. Horns of this kind are usually laminated like pie-crust.

Nail horns are simply the greatly elongated and thickened nails found especially on the big toes of bed-ridden and dirty patients. These nails sometimes attain the length of 7 cm. (2.73 in.), and resemble miniature ram's horns.

Epithelioma.—This genus always arises in the stratified epithelium of skin or mucous membrane. It is characterized by cone-shaped ingrowths of epithelium which invade the subjacent tissue.

The genus consists of one species—epithelioma—which may arise on any surface covered with stratified epithelium, but is more common in regions where there is a transition from one kind of epithelium to another, and especially where skin and mucous membrane come in relation to each other—*e. g.*, the anus, the vulva, and the lip. Other common situations are the tongue, the gums, and the mucous membrane of the cheek. It sometimes occurs at the edges of cicatrices and chronic ulcers. Many examples have been reported in which it has attacked the base of an old wart or a wart horn.

An epithelioma may make its appearance as a wart-like growth, more frequently a small circular ulcer with raised rampart-like edges, or as a fissure. Epithelioma is particularly apt to arise on the scrotum of chimney-sweeps.

Although the three clinical varieties of epithelioma look so different, they are identical in structure. When sections are cut so as to include the margin of the ulcer and underlying tissue, the surface-epithelium will be seen invading it in the form of long, simple or ramified columns. Weichselbaum has pointed out that the cells composing the columns retain more or less the characters of the epithelium from which they originate. When the cones grow rapidly, the cells become flattened, and some finally cornify (Fig. 206). In this way the so-called epithelial pearls or nests are produced. When lateral pressure is made on a fresh epithelioma, whitish plugs are forced out; these plugs are the cellular cones.

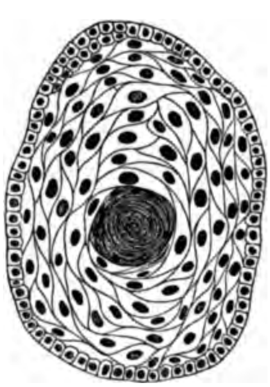

FIG. 206.—Arrangement of the cells in epithelioma.

The primary ulcers, when left to themselves, may extend and involve extensive tracts of tissue, or fungate and form large granulating, cauliflower-like masses. In both conditions the superficial parts are continually cast off in a foul, fetid discharge containing sloughs, cellular detritus, pus, and blood.

Vascular tissues involved in the epithelioma are quickly infiltrated and destroyed; even bone is rapidly eroded. Not the least remarkable feature of this disease is the rapidity with which it infects the adjacent lymph-glands. The large size which the glands attain in some instances is out of all proportion to the dimensions of the initial lesion, for an epithelioma 1 cm. (0.4 inch) in diameter will lead to the formation of a mass of enlarged lymph-glands as big as a cocoanut. The gland-complication of epithelioma is always a serious element of danger,

for in some situations the enlarged glands may compress vital structures, such as the trachea or esophagus; or, when they disintegrate and ulcerate, large blood-vessels may be opened, and fatal bleeding ensue. Dissemination is unusual in epithelioma.

In whatever situation it arises, epithelioma usually destroys life quickly from exhaustion, bleeding, pain, or the implication of such structures as the pleura, trachea, esophagus, urethra, and bladder, or even the dura mater, according to the situation of the initial lesion. Septic pneumonia is a common mode of death when the mouth, nasal passages, fauces, larynx, or gullet are implicated in the ulceration. Even when freely removed, the disease is very apt to recur locally, or far more frequently in the lymph-glands.

Adenomata.—An adenoma is a tumor constructed on the type of, and growing in connection with, a secreting gland. The species of this genus are determined by the glands in which they arise. The chief species of adenomata are—mammary, sebaceous, thyroid, pituitary, prostatic, parotid, hepatic, renal, ovarian, gastric, intestinal, and uterine. In some glands, such as the liver, parotid, mamma, and thyroid, they occur as encapsuled tumors. In the intestine, especially the rectum, and in the cervical canal of the uterus they appear as pedunculated bodies (polypi). Often the acini of an adenoma become distended with perverted secretion and form large fluid-containing spaces. Such sometimes receive special names; thus, in the mamma it would be called a cystic adenoma or an adenocele; in the thyroid gland, a bronchocele; in the ovary, a multilocular ovarian cyst.

In size, adenomata exhibit great variations; some rarely exceed the dimension of a pea, others may attain the size of a foot-ball. In number they vary greatly; one only may exist, or many may be present.

The liability of secreting glands to become the seat of adenomata is very variable; thus, they are excessively common in the mamma, ovary, and thyroid; rare in the liver, kidney, and pituitary body; and, though common in the prostate and parotid glands, are almost unknown in the submaxillary, sublingual, lacrimal, and pancreatic glands.

The following statements hold good for all the species: When completely removed, there is no recurrence; they do not infect the neighboring tissues or lymph-glands, nor give rise to secondary deposits. When an adenoma causes death, it is in consequence of mechanical complications due to its environment. Thus a small tumor of the pituitary body will cause death from pressure on the brain; a bronchocele may injuriously narrow the trachea; an intestinal polypus occasionally induces intussusception; and a small prostatic adenoma will sometimes jut into the vesical orifice of the urethra and cause death by renal complications.

As a rule, adenomata are tumors of adolescence and adult life. Hepatic and prostatic adenomata occur commonly after the mid-period of life. Cystic adenomata are liable to secondary changes of some importance; thus, the fluid contained in cysts which have existed several years in the mamma, thyroid, or ovary often contains large quantities of cholesterin. Hemorrhage not infrequently takes place in large cysts of these glands, and Reverdin once found a large number of mulberry-like bodies, composed of coagulated fibrin, in a large bronchocele

in an old man. The walls of very old bronchoceles are liable to be completely calcified; and calcareous patches are sometimes found in old cysts of the ovary and mamma. A much more important change is the formation of villi (papillomata) and buds of glandular tissue on the inner walls of cystic adenomata. They are common in the breast and ovary, and have been observed in the thyroid.

Carcinomata (*Cancer*).—A carcinoma, like an adenoma, is a tumor arising in, and mimicking the structure of, a secreting gland; but it differs from an adenoma in the fact that the structural mimicry is incomplete. The epithelium, instead of exhibiting the regular disposition so constant in adenomata, is, in cancers, collected in the acini and ducts in irregular clusters, or fills them so completely as to give rise to the appearance, when examined microscopically, of sections of epithelial columns. Carcinomata are malignant tumors.

The species of carcinomata depend upon the glands in which they arise. The chief are—mammary, uterine, thyroid, prostatic, renal, pancreatic, hepatic, ovarian, gastric, and intestinal. Rarer species arise in specialized mucous glands, such as those of Cowper, Bartholin, and Tyson, the mucous glands of the maxillary sinus (antrum), and the larger bronchi.

Carcinomata infiltrate surrounding tissues, and extend beyond the gland in which they originate; they are very prone to involve surface-

FIG. 207.—Adenoma of the endometrium.

tissues, to ulcerate, and quickly to infiltrate lymph-glands in the neighborhood. A marked feature of carcinomata is their tendency to undergo degenerative changes and necrosis.

The relationship between secreting glands, adenoma, and carcinoma may be studied in the uterus. The glands in the endometrium are tubular and lined with columnar epithelium.

Adenomata arising in the endometrium preserve the tubular type of glands (Fig. 207), whereas carcinoma originating in the same situation consists of masses of these tubules, greatly enlarged and stuffed with epithelium (Fig. 208).

Cancers are exceptionally liable to become disseminated and give rise to knots or nodules known as secondary deposits, which may make their appearance in any organ or tissue of the body, even the bones. These cancerous deposits are due to minute portions of the primary tumor being transported by the lymph- and blood-vessels as

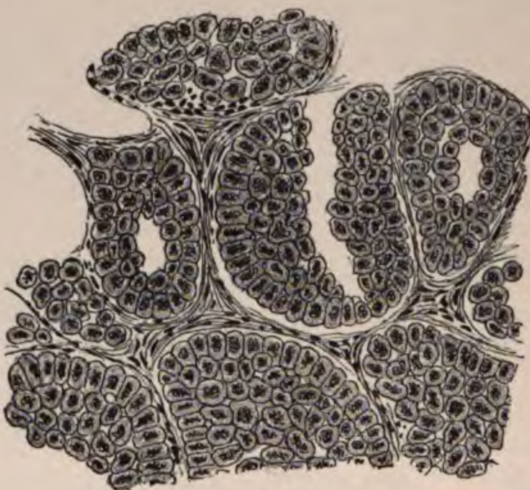

FIG. 208.—Carcinoma of the endometrium.

minute emboli, which, when lodged in suitable situations, engraft themselves and form nodules which in histologic characters reproduce the parent tumor. So exact is this reproduction that the nature and situation of the primary tumor may be accurately inferred from an examination of a secondary nodule. The amount of dissemination varies widely. In some cases the secondary knots may be limited to the liver, whilst in another and apparently identical case, in so far as structure is concerned, they occur in scores, deposited in almost every organ of the body, even in the bones.

Although every secreting gland is liable to become the seat of cancer, yet some are much more prone to it than others. The commonest situations are the female mammæ and the glands of the cervical canal of the uterus. Cancer of the glands at the pyloric orifice of the stomach and in the colon and rectum is common in both sexes, but it is somewhat uncommon in the prostate and thyroid glands.

In some situations the relative frequency of carcinoma and sarcoma has not been determined, the two conditions being comprised under the term malignant disease. Thus, malignant tumors of the antrum are generally classed as sarcomata; but many of the most deadly tumors which occupy this cavity are carcinomata arising in the racemose glands lodged in its mucous membrane.

Carcinoma in the restricted sense now enforced by pathologists is unknown before puberty; it is rare before twenty-five; the liability increases with each decade of life. These facts are the reverse of those observed in adenomata.

The modes by which cancer kills varies with its situation and the nature of the organ implicated. Thus, cancer of the pyloric glands blockades the orifice and causes death by starvation; mammary cancer invades the pleura and gives rise to secondary deposits in lungs, liver, brain, etc.; uterine cancer is apt to be fatal from bleeding, from uremia due to the vesical extremities of the ureters and the bladder being involved mechanically in the growth, or from the renal channels becoming infected by septic micro-organisms which flourish in the discharges and necrotic tissue of the cancer; carcinoma of the colon will cause death from intestinal obstruction, septic peritonitis, or actual perforation; carcinoma of the thyroid gland will lead to fatal dyspnea; and cancer of the antrum causes death by pneumonia due to the direct inhalation of septic material.

Adenomata and Carcinomata of Sebaceous Glands.—Although the preceding account of adenomata and carcinomata holds good for glands in general, it is necessary to consider separately the diseases of sebaceous glands.

Sebaceous Cysts.—In its best-known form a sebaceous gland appears as an appendage to a hair-follicle, the secretion of the gland being discharged into the follicle. In some situations, especially in the skin of the nose and cheek, the hair is so delicate and the glands are so large that the hair seems to be an appendage of the gland; in other situations—*e. g.*, the corona of the penis, and the labium minus—the glands are very large, but hair is absent. In every situation where these glands exist (even in ovarian dermoids), the walls of the acinus are apt to become thickened and the gland-secretion (sebum) retained, giving rise to a definite rounded swelling known as a sebaceous cyst. Such a cyst forms a rounded circumscribed swelling lodged in the skin; and in all situations, save the scalp, close scrutiny will reveal a small circular black dot or dimple, indicating the orifice of the duct. Sometimes the orifice is open, and slight pressure causes sebum to exude. These cysts may be as small as coriander seed, and they rarely exceed the dimensions of a tangerine orange. Many may grow concurrently in the same individual, especially in the scalp.

Sebaceous cysts have a capsule of fibrous tissue lined with stratified epithelium. They contain a pultaceous matter consisting of shed epithelium, fat, and cholesterin; sometimes the cyst-contents consist of pure sebum resembling Chinese white. An arachnid, the *demodex folliculorum*, is often present. The capsule of a sebaceous cyst, especially in the scalp, is thick and laminated like an onion.

These cysts are liable to secondary changes; thus, the cyst-wall may inflame and suppurate, the cyst-contents sometimes decompose, and occasionally calcification occurs. An inflamed cyst may burst, and its wall become converted into a large fungating mass, particularly on the scalp (Fig. 209); this condition is apt to be mistaken for epithelioma, especially when the associated lymph-glands are enlarged. These cysts are not infrequently the source of one variety of cutaneous horn.

Sebaceous Adenomata.—It has been so customary to regard all tumors arising in sebaceous glands as simple cysts that it is quite an exceptional event for them to be submitted to microscopic examination.

However, this mode of investigation serves to show that some of them are solid and resemble the exuberant masses which form upon the nose, and which are often referred to as "nasal lipomata." They are due to overgrowth of the large sebaceous glands so abundant in the skin of the nose. A careful microscopic examination of supposed "fungating wens" will show that many of them are ulcerating sebacous adenomata.

FIG. 209.—Ulcerating sebaceous adenoma (fungating wen).

Sebaceous Carcinoma (*Rodent Ulcer*).—In British writings on Surgery it has been customary for many years to describe under the name of rodent ulcer a form of cancer which exhibits extraordinary clinical characters. In its common form a smooth, rounded knob of about the size of a split pea is noticed on the skin of the face, either on the nose, eyelids, orbital angles, or cheek. This knob may remain for years (seven, eight, or twelve) and cause no inconvenience save unsightliness; then without obvious reason it may ulcerate and destroy the surrounding skin and underlying tissues, involving all tissues in its vicinity—skin, muscles, fat, cartilage, eyeball, and bone—and producing horrible destruction of the face, in some cases even destroying the base of the skull and meninges and exposing the brain. To produce such terrible effects the disease requires sometimes five, ten, or even more years. In its course it destroys everything, never cicatrizes, and is painless.

In recent years the histology of the early knobs which mark the beginning of the disease has been investigated with great care. All observers agree that the disease begins as a solid growth beneath the epidermis. If in this stage the nodule is excised and sections are examined microscopically, the nodule will be seen to consist of gland-ducts filled with epithelium, though sometimes they take the form of solid cylinders. In the latter stages, when ulceration is in full sway, these appearances are lost.

The origin of the initial knob has been ascribed to the following sources: 1. Sebaceous glands; 2. Sweat-glands; 3. The hair-follicle; 4. The outer layer of the root-sheath of a hair; 5. Epithelial remnant in the course of the facial fissures; 6. Vestiges of the tear-pits of ruminants.

My own investigations induce me to ascribe its origin to the sebaceous glands.

Although rodent cancer arises mainly in the facial situations already mentioned, it may occur on the neck, and has been met with on the

trunk, but never, so far as I know, on the limbs. It occurs most frequently in advanced life, but is not uncommon between thirty and fifty. It has been recorded at the age of twenty, but never before puberty (fifteen years). It is more frequent in men than in women. The extraordinary features which distinguish it from the general species of carcinomata and epithelioma are the following: 1. It does not infect lymph-glands; 2. It does not disseminate; 3. Though, as a rule, solitary, it may be, and often is, multiple; 4. Its duration may extend over many years.

Happily, of all species of carcinomata, this gives the best results to adequate operative treatment. When freely excised in the early stages, recurrence is very exceptional. Even in the very late stages, as Moore demonstrated in 1867, bold and free excision usually gives excellent results, so far as the course of the disease is concerned.

III. DERMOIDS.

These are tumors furnished with skin or mucous membrane, occurring in situations where these structures are not found under normal conditions. Dermoids only possess tissues which naturally belong to skin or mucous membrane.

The group contains four genera: 1. Sequestration dermoids; 2. Tubulodermoids; 3. Ovarian dermoids; 4. Dermoid patches (moles).

Sequestration Dermoids.—The species of this genus arise in detached or sequestered portions of the surface epithelium, mainly in situations where, during embryonic life, coalescence takes place between

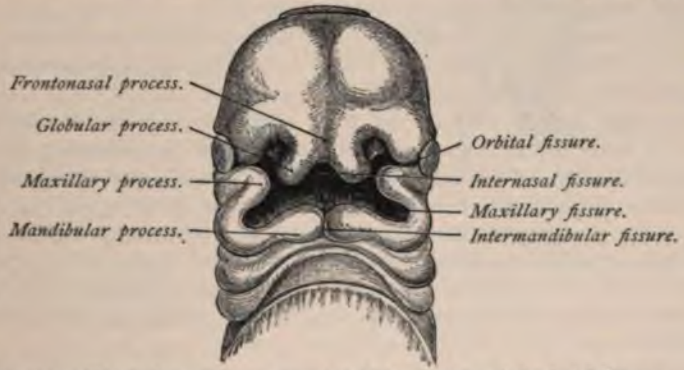

FIG. 210.—Head of an embryo, showing the disposition of the facial fissures (semi-diagrammatic).

skin-covered surfaces. They are met with in the mid-line of the trunk, from the occipital protuberance along the spine to the coccyx, through the perineum (including the scrotum and penis), and onward through the mid-line of the abdominal and thoracic wall to the neck. In the face and neck they arise in the lines of the facial and branchial fissures. In the pinna, dermoids arise in the lines of fusion of the tubercles out of which the pinna is formed.

The characters and the modes by which dermoids arise may be illustrated in the nose. In the early embryo the central part of the

face is represented by an opening from which five fissures radiate (Fig. 210). The upper pair are the orbitonasal, the two lower are the maxillary fissures, and a fifth the intermandibular. The median fold projecting into the opening from above is the frontonasal process, which ultimately forms the nose. Each angle of the frontonasal plate is rounded and is known as the globular process; they unite to form the alæ of the nose, the premaxillæ, and the central median piece (the philtrum) of the upper lip. The elongation of the frontonasal process lengthens the orbitonasal fissures. The sides of the frontonasal plate coalesce superficially with the maxillary processes, the lines of fusion being permanently indicated in the adult by the nasofacial sulcus, and on the deep surface by the lacrimal duct. This brief account of the development of the face indicates that the nose is related with three fissures: the orbitonasal on each side; the internasal, in the mid-line of the nose, marks the line of union of the globular processes. In each of these situations faults of three kinds occur: 1. The fissure persists; 2. It may close imperfectly and leave a fistula; 3. A portion of surface epithelium becomes sequestered and forms a dermoid.

FIG. 211.—The nose, to show the lines of coalescence.

In the case of the nose itself, the internasal fissure is very apt to be imperfectly obliterated and leave a fissure, and from its skin-lined recesses hairs may sprout.

Dermoids at the root of the nose arise in a different manner. In the early embryonic stages the frontonasal process consists of hyaline cartilage covered with skin. Gradually the nasal bones develop between the skin and cartilage, eventually causing the underlying cartilage to disappear. In the process of separating skin from cartilage, fragments of surface epithelium become sequestered and give rise to dermoids. Dermoids of the scalp arise in this way, and occasionally project on the deep surface of the cranium, and cause death by interfering with the brain.

Sequestration dermoids rarely attain a large size; the majority do not exceed 5 centimeters (2 inches) in diameter. Structurally they appear as cysts lined with skin which resembles the cutaneous investment of the parts in which they arise. Thus, a dermoid of the eyelid will have its skin-lining like that of the eyelid; in the scalp, the hairs and glands are like those of the normal scalp, and so on. Occasionally a dermoid appears as a solid tumor, the skin covering its outer surface. Sequestration dermoids very rarely contain teeth. Dermoids in the nasofacial sulcus are rare, whilst they are of frequent occurrence in the neighborhood of the orbit, but are more common at the temporal than at the nasal angle.

Implantation Cysts.—It has long been recognized that dermoids do

not occur in the limbs; yet, occasionally, small skin-lined cysts are met with in the skin of the hand and fingers. It has been demonstrated that these cysts are the results of injury, such as pricks and cuts, whereby fragments of the skin are carried into the subcutaneous tissue and subsequently give rise to skin-lined cysts. These are called implantation cysts, from the manner of their origin. They may attain the size of a bantam's egg, and occur not only in the limbs, but on the trunk, scalp, and face. Very many examples have been recorded in the cornea and iris as the result of punctured wounds of the globe, as well as the consequence of operations, such as iridectomy and cataract-extraction. The cysts are considered here, since they serve as experimental proof that sequestered portions of skin may act as tumor-germs.

Tubulodermoids.—In the human embryo there are certain canals and passages which normally disappear before birth. These are known as obsolete canals. Three of these, the thyroglossal duct, the branchial clefts, and the postanal gut, are occasionally the source of dermoids.

Lingual Dermoids.—The variety which arises in the center of the tongue, between the geniohyoglossi muscles, has its origin in the persistent glossal segment of the thyroglossal duct (Fig. 212).

FIG. 212.—The thyroglossal duct (Marshall).

Rectal Dermoids.—There are three situations in relation with the rectum in which dermoids arise: 1. They may hang as polypi from the mucous membrane; 2. They sometimes lie between the rectum and coccyx, extending upward into the hollow of the sacrum; or, 3. They project from between the rectum and coccyx as huge congenital tumors (familiar as congenital sacrococcygeal tumors). The last two species arise in persistent segments of the postanal gut.

Branchial Dermoids.—These arise in persistent branchial fissures. They are congenital, and lie, as a rule, beneath the deep cervical fascia.

Tubulodermoids, apart from their mode of origin, differ from the sequestration genus in the following points: They often attain very large proportions, exhibit a more complex structure, and not infrequently contain teeth.

Ovarian Dermoids.—This genus differs from other dermoids in their mode of origin as well as in the great variety of structure they contain. The ovarian dermoid arises in that region of the ovary containing the follicles (the oöphoron), and the glandular and epithelial elements are derived from the rich follicular epithelium.

An ovarian dermoid may contain hair (Fig. 213) which is sometimes a meter (39.37 inches) in length; skin-glands of every variety—sebaceous, sudoriparous, and mammary—also horn, nail, and epithelial

pearls; and collections of shed epithelium which sometimes assume the form of pills, and may number 3000 or 4000 in one cyst. Bone is not uncommon, and teeth (Fig. 214) may be numerous (1 to 300).

FIG. 213.—An ovarian dermoid.

Ovarian dermoids sometimes attain prodigious proportions (50 lbs.) There is no reliable evidence of the existence of an ovarian dermoid in a child under one year of age. In this respect they differ from sequestration dermoids, which are nearly always congenital.

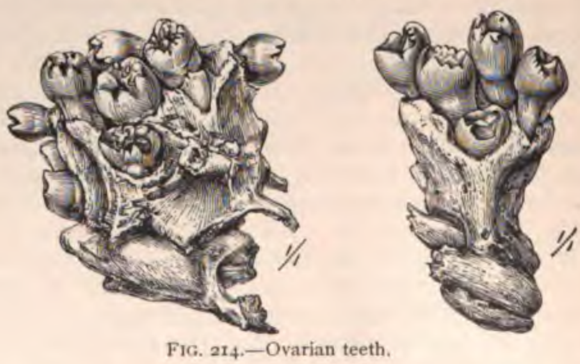

FIG. 214.—Ovarian teeth.

The ovary is the only abdominal viscus in which dermoids arise primarily, but an ovarian dermoid may rupture and, by infecting the peritoneum, give rise to a "crop of small dermoids."

Moles.—This term is applied to a congenital, pigmented, and usually hairy patch upon the skin. Moles vary greatly in size. Some are like dots, others may be as big as the palm, and occasionally a mole may involve half the face or trunk. They commonly occur where hair is scanty, and are conspicuous objects. Moles sometimes arise on the scalp and conjunctiva. The hair on moles is usually short, but it may be 10 centimeters (3.9 inches) or more long. It is furnished with sebaceous glands; sweat-glands are often present, even in the conjunctival variety. The most important histologic feature in moles, both hairy and hairless, is the fact that the tissue immediately underlying them has a disposition like that characteristic of an alveolar sarcoma.

A mole bleeds freely when its surface is abraded; it is liable to ulcerate; and, later in life, is prone to become the starting point of a melanoma.

Teratomata.—A teratoma is an irregular conglomerate mass, containing the tissues and fragments of the viscera of a suppressed fetus, attached to an otherwise normal individual. Strictly, the consideration of teratomata belongs to teratology, but certain species are very apt to be confounded with dermoids.

When a single ovum gives origin to two embryos, they may remain separate or be conjoined. Occasionally, when the embryos remain distinct and have a common placenta, one embryo goes on to full development, but the other becomes an "ill-formed lump," sometimes furnished with arms and legs, but often having the limbs blended with the trunk. These are known as *acardiac fetuses.* When the twins are conjoined, both may go on to full development, or one may become suppressed and remain as an imperfectly developed fetus attached to one that is fully formed. The bearer of a *parasitic fetus* of this kind is termed the autosite. The degree to which the parasitic fetus is developed varies very greatly. When the limbs are developed, there is no difficulty in recognizing it; but when it is a sessile mass, there is more difficulty.

An acardiac fetus differs from a parasitic fetus merely in the fact that the former is connected with its twin by means of the placenta, whilst the latter is directly attached to its companion. Parasite fetuses may be attached to any part of the head or trunk of the autosite. The posterior sacral region is perhaps the commonest. In a few rare cases the suppressed fetus has been found on the posterior wall of the belly or the thorax.

The essential difference between a teratoma and a dermoid is this: A teratoma contains formed organs, such as intestine, liver, kidney, etc., and complete bones, such as a vertebra, perhaps with a piece of spinal cord or a completely formed limb; dermoids, on the other hand, contain skin or mucous membrane (sometimes both) and such structures—glands, hair, nails, teeth, etc.—as are normally derived from skin and mucous membrane.

IV. CYSTS.

Cysts (or cystomata) result from the abnormal dilatation of preexisting tubules or cavities. In the simplest forms they consist of a wall, usually composed of fibrous tissue, but not infrequently mixed with plain muscle-fiber. The cyst-contents may be mucus, bile, saliva,

etc., according to the nature of the organ with which the cyst is connected.

Cysts may be arranged in four genera: 1. Retention cysts; 2. Tubulocysts; 3. Hydroceles; 4. Gland-cysts.

Retention Cysts.—When the duct of a gland is obstructed, the secretion, hindered from escaping, accumulates in the ducts and acini, and dilates them. If the obstruction be maintained or oft-repeated, the gland-tissue atrophies, and finally the gland and its duct are converted into a fluid-containing sac or cyst. Typical retention cysts arise in connection with hollow organs the inner walls of which are provided with glands, such as the uterus, gall-bladder, and vermiform appendix.

Retention cysts may, and often do, reach very large proportions, endangering life by interfering with the functions of the organ in which

FIG. 215.—Urinary organs of a fetus with imperforate urethra. On one side the ureter is dilated into a large cyst, and the renal pelvis is sacculated (hydronephrotic); the opposite ureter is narrow, and the uriniferous tubules are ectatic.

they arise, or by mechanically disturbing adjacent viscera. Frequently, pathogenic micro-organisms gain access to the contents of cysts, and establish suppuration with all its attendant evils.

Tubulocysts.—This genus includes cysts arising in functionless ducts—*e. g.*, the urachus, vitello-intestinal duct, parovarian tubules, and Gärtner's duct. Functionless ducts must not be confounded with obsolete canals.

Hydroceles.—These cysts are due to excessive accumulation of fluid in a diverticulum or pouch of the peritoneum. The following are the chief species: hydrocele of the tunica vaginalis testis; hydrocele of the canal of Nuck; hydrocele of hernial sacs; hydrocele of the ovarian pouch (probably confined to a few mammals); omental hydroceles, or cysts due to accumulation of fluid between the layers of the great omentum.

Gland-cysts.—In many compound glands the secretion escapes by a common duct. Thus, in the salivary glands—*e. g.*, the parotid—the excretory conduit is known as Steno's duct; the duct of the kidney is the ureter, and that of the submaxillary gland is known as Wharton's

FIG. 216.—Cyst due to dilatation of a milk-duct. It had existed for many years, and contained much cholesterin.

duct. In other compound glands the secretions open into a number of channels, each with a discrete orifice. For example, the mammary or milk-ducts open separately on the apex of the nipple; the lacrimal and sublingual glands have many ducts with separate terminations. In compound glands of this kind a distinction must be made between cysts arising in the ducts or in connection with the acini of the glands. For instance, in the kidney, obstruction to the main duct (ureter) leads to hydronephrosis, but when the uriniferous or gland-tubes form cysts, then the organ becomes a conglomerate cystic body (Fig. 215). This is well seen in the mamma, where a cyst arising in the milk-duct is situated near the base of the nipple (Fig. 216): by pressure the fluid may be made to exude through the duct; but when the glandular acini become cystic, the organ is dotted throughout with fluid-containing cavities.

A cyst due to distention of Wharton's duct is called a ***ranula;*** one arising in the ducts of the lacrimal gland is termed ***dacryops.***

Pseudocysts.—There are many conditions often classed as cysts which may with greater propriety be arranged as a sub-group containing four genera: 1. Diverticula; 2. Bursæ; 3. Neural cysts; 4. Parasitic cysts.

Diverticula.—The term diverticulum denotes a hernia or protrusion of the lining membrane of a cavity through a defective spot in its walls. Diverticula occur in mucous canals—*e. g.*, the pharynx, esophagus, larynx, trachea, intestine, and bladder. A hernial protrusion of the synovial membrane of a joint is called a synovial cyst, and in the case of tendon-sheaths, a ganglion. Localized protrusions of the meninges of the brain and spinal cord are known as meningoceles.

Bursæ.—Where muscles or their tendons glide over osseous prominences, and in situations where the skin is exposed to intermittent pressure combined with friction, membranous sacs filled with glairy fluid occur. These are known as bursæ, and are often a source of inconvenience, especially when they inflame. Common examples are the prepatellar and olecranon bursæ. Very large examples are sometimes found over the tuberosity of the ischium and the great trochanter. Troublesome bursæ are found under many corns and associated with bunions.

Neural Cysts.—This genus includes the abnormal conditions of brain known as encephalocele and dilatation of the cerebral ventricles (hydrocephalus). It also includes malformations of the spinal cord included in the term spina bifida.

Parasitic Cysts.—This includes echinococcus cysts and colonies and the cysticercal stage of the tenia.

CHAPTER XVI.

FRACTURES.

GENERAL CONSIDERATIONS.

FRACTURE, in the general surgical sense, is the breaking of hard animal tissue; in the special surgical sense employed here, the term is applied to the breaking of bone. It should be borne in mind that a fracture is a wound—a wound of bone—and that in its etiology, symptoms, pathology, and treatment it is amenable to the same laws which govern wounds in other tissues.

Varieties.—The varieties of fracture, for convenience of classification, may be divided as follows:

A. **According to the Lines of Fracture.**—The terms transverse, oblique, dentate, spiral, V-shaped, T-shaped, and longitudinal fracture are self-explanatory. A *stellate fracture* is one in which multiple lines of fracture radiate from a central point. By *comminuted fracture* is understood a breaking of bone into small fragments: this is usually caused by direct, crushing injuries. When a bone is broken in several places, more widely separated than in comminuted fracture, the term *multiple fracture* is applied. A splintered fracture is one in which a small, superficial fragment of bone is chipped off. This sometimes occurs as the result of muscular action, whereby a fragment of bone to which the muscle is attached is torn away. The term is also applied to multiple parallel lines of fracture, close together, and terminating in the free surface or broken end of a bone. *Punctured* or *penetrating fracture* is usually a variety of comminuted fracture, caused by a penetrating instrument or projectile. It may, however, be caused by a sharp instrument which produces only a separation of the bone, by parting its substance to either side as it enters. By *gunshot fracture* is understood the fracture produced by a projectile from a firearm. Such fractures vary from an ordinary penetrating fracture to the most severe comminuted fracture. They are of especial importance because they are always associated with a lacerated, usually infected wound of the soft parts. A fracture with loss of substance is one in which, at the time of injury, a portion of the bone is separated or entirely removed from its normal connections.

B. **According to the Degree of Fracture.**—A *complete fracture* is one in which the bone is divided into two or more parts by a line or lines of fracture involving its whole thickness. When the bone is not completely separated into two or more parts—as in the case of the shaft of a long bone with a crack passing only partly across its longitudinal axis, and in the case of a flat bone, when the fracture-line does not extend completely from one side of the bone to the other—the term *incomplete fracture* is used. To this second class belongs the

green-stick or *bending* fracture—that is, a fracture caused by the bending of a long bone to such a degree that the bone-tissue separates on the side which suffers traction, and does not separate upon the opposite side, or side of compression. *Fissured fracture*, or fissure, is a form of the incomplete variety in which a single line or lines of fracture traverse only a part of the thickness, breadth, or length of a bone. It is most commonly observed in the skull, and sometimes as a longitudinal fracture of the long bones. In the long bones it may be produced transversely or obliquely by the same force that causes green-stick fracture in a less brittle bone. *Depressed fracture* is usually incomplete; though there is a form of complete depressed fracture in which an area involving the whole thickness of the bone is completely separated and driven in. The *incomplete depressed fracture* consists in the bending or pressing in of an area, without a circumferential separation involving the whole thickness of the bone. The crushing in of the bony wall of an antrum or sinus or of the vitreous layer of a bone into the underlying cancellous structure constitutes an *incomplete depressed fracture*.

C. **According to the Displacement of the Fragments.**—*Depressed fracture* of the complete variety is observed especially in the skull, and is of importance because of the accompanying injury to the underlying viscera. *Fracture with transverse displacement* is one occurring —as is the case with the five following varieties—in long bones, and is characterized by a displacement of one or both fragments in a direction transverse to the long axis of the bone. When the degree of displacement is greater than the diameter of the bone, and in the absence of surrounding resistance, the contraction of the parts tends naturally to the production of fracture with overriding. *Fracture with rotary displacement* is the result of the destruction of the normal relations by a rotation of one or both fragments upon the long axis. *Fracture with angular displacement* not only occurs in complete fractures, but is usually the only displacement in incomplete or green-stick fractures of the long bones. It is very variable in its degree, and may be associated with lateral dislocation to such an extent that a T-shaped displacement results. When the displacement occurs in the direction of the long axis of the bone, the lesion is designated as *fracture with longitudinal displacement*, though the term is understood to apply only to fractures with longitudinal separation or drawing apart of the fragments. An *impacted fracture* is the driving of one fragment into another, or the telescoping of the bone.

D. **According to the Location of the Fracture.**—The separation of an epiphysis is an accident peculiar to young persons. It is of importance because, in the healing, the cartilage which separates the epiphysis from the diaphysis often becomes prematurely ossified, and thus the subsequent longitudinal growth of the bone is interfered with. Fracture of the shaft is the most frequent of fractures. Fracture of the head of a bone, because of its almost invariable involvement of the articular surface, assumes a special importance. Fracture of the neck of a bone may or may not involve that part of the neck which lies within the joint. The term "fracture of the extremity of a bone" is included in the above-mentioned classes. *Intracapsular* or *intra-articular* fracture is a

fracture lying wholly within the joint. *Extra-articular* fracture is one lying in close relation to the joint, but still external to the joint-capsule. When the line of fracture involves the bone both within and without the joint, it is designated as *mixed fracture.* Intercondyloid fracture is a fracture which enters a joint between the condyles. The separation of an apophysis is similar to the separation of a splinter by direct external violence or muscular action. By *multiple fracture* is understood the simultaneous breaking of two or more bones.

E. **According to the Presence or Absence of other Injuries.**—A *simple* or *closed fracture* is one that is not complicated by a wound extending from the seat of fracture through the overlying skin or mucous membrane. A *compound* or *open fracture* is one that is associated with such a wound. This variety of fracture is of the greatest importance, because it adds to the bone-injury the possibility of all the dangers and complications of an open wound. The dangers inherent in a compound fracture are greater than those in a simple fracture, complicated by a wound of the soft parts of the same extent, not connected with the break in the bone. The combination with a fracture of an open wound involving the soft tissues adds an extra hazard which is entirely out of proportion to the combined dangers of the two conditions when existing separately. A *complicated fracture* is one associated with a wound of a large nerve, vessel, joint, or internal organ, or with the dislocation of a joint with which a broken bone articulates.

F. **According to the Etiology of the Fracture.**—Under this heading are two great classes—*traumatic fractures* and *pathological fractures.* The first occur as the immediate result of violence to healthy bone, or to bone which is strong enough to withstand a considerable degree of breaking force. The second occur in bones which have become so fragile, as the result of pre-existing local disease, that a slight degree of force suffices to cause a fracture.

The traumatic fractures are the following: *Fracture by direct force* implies that the fracture occurs at the location where the primary force strikes the bone. *Fracture by indirect force* implies that the fracturing force is applied at a point remote from the place where the bone breaks, and is transmitted through the bone. It is customary to speak also of *fracture by twisting* and *fracture by traction.* *Fracture by contre-coup,* or opposite-stroke, is a term applied to that form of indirect fracture of the skull in which the fracture occurs on the opposite side from that at which the force is applied. These are fractures by external violence. In fracture by muscular contraction the violence is done by force generated within.

(For the varieties of pathological fracture, see the Predisposing Causes of Fracture.)

Etiology.—Under this head are considered the predisposing and exciting causes of fracture. Predisposing causes which induce abnormal fragility of bone are caries and necrosis; tumors of bone, either primary or metastatic; pressure or encroachment upon the bone by extra-osseous tumors; osteomyelitis; osteoporosis; fragilitas ossium; osteitis deformans; echinococcus; actinomycosis; syphilis; tuberculosis; atrophy as a result of disuse or circulatory defects; fatty

degeneration; mercurial poisoning; rheumatism and gout. Aside from these more particularly local causes are certain general disturbances which render bone more liable to fracture. These are rickets; osteomalacia; scrofula; insanity; locomotor ataxia; general paralysis, and other diseases involving the trophic centers; old age and general inanition. In some families there is an hereditary liability to fracture.

There are certain other predisposing causes of fracture which do not depend upon pathological changes. Persons of the male sex, because of greater exposure to violence, sustain more fractures than the female. In certain occupations the liability to fracture is greater than in others. The occurrence of fracture is influenced by the season. It is not true that bone is more brittle in cold weather, but, because of the more tonic state of the muscular system in cold weather, the joints are held more rigidly, and thus injury is more apt to cause fracture. The presence of ice in certain seasons adds to the danger. The shape and the situation of certain bones are factors in their predisposition to fracture.

The exciting causes of fracture are external violence and muscular action. By external violence is meant the violent or forcible contact of a part of the body with some external body or force. Such a force may be the cause of fracture by direct action—that is, the fracture may occur directly at the place where the external force is applied; as, for example, when the leg is struck, and breaks at the place of contusion. Or the force may act indirectly, and cause a fracture at some point remote from the place where the external force meets the body; as, for example, the breaking of the radius by a fall upon the hand. Muscular action is not an uncommon cause of fracture. The violence is done by the sudden and strong contraction of muscle, acting usually upon some bony prominence or bone which projects as a lever over its underlying fulcrum. The most common seats of fractures caused in this way are the olecranon process of the ulna, which is broken by the triceps muscle, and the patella, which is broken by the quadriceps extensor muscle.

Symptoms.—The immediate symptoms of fracture are local and general.

Local Immediate Symptoms.—*Abnormal mobility* is a symptom which depends upon the possibility of displacement of the fragments. When the bones of a limb are broken, it may be possible to move the limb in directions in which the normal limb could not be moved, and the size of the arc through which the limb normally moved may be increased.

False Point of Motion.—The above symptoms depend upon the presence of an abnormal point of motion in the bone. The fragments may remain in exact apposition, or displacement may be present.

Crepitus.—This is the peculiar grating feeling that is imparted to the examining hand when broken-bone surfaces are rubbed together. Sometimes it can be detected by the sense of hearing. It is also manifested to the patient by the sense of feeling.

These are the most important symptoms of fracture. They apply more particularly to the fractures of the long bones, and belong especially to the class of complete fractures. Crepitus may be absent

because of the incompleteness of the fracture, or because of the presence of blood-clot or other soft tissue between the fragments, or because of an overriding or impaction of the same. In the case of the fracture of a bone which has a parallel companion, the latter acts as a splint, and these symptoms may be elicited with difficulty. This difficulty is increased in the cases with very thick limbs, and also in V-shaped and firmly interdigitating fractures.

Deformity.—The degree of deformity about a fracture depends largely upon the degree of displacement of the fragments. Aside from the immediate deformity as a result of such displacement, there must needs be about a fracture more or less injury to the soft tissues, the degree of which depends much upon the degree of the displacement. This tearing of the soft tissues causes a swelling, due to the extravasation of serum and the escape of blood from the torn vessels. However much this may amount to, there is always bleeding from the broken-bone surfaces themselves. The deformity may also be increased by open wounds of the soft parts.

Loss of Power.—The loss of mechanical support, the pain caused by movement, and paralysis as the result of nerve-injury are the factors upon which this symptom depends. It varies much with the character of the fracture and the disposition of the patient. Usually the loss of power is pronounced.

Pain.—This symptom depends upon the wounding of nerves, and upon pressure upon the nerves by bone-fragments and extravasated blood and serum. Ordinarily the pain of fracture is not severe, except when there is motion which permits the bone-edges to irritate the adjacent nerve-filaments.

Tenderness.—This depends upon all the conditions which produce pain and upon the application of pressure from without.

Muscular Spasm.—As a result of the mechanical irritation of the muscle itself by the edges of bone or other lacerating or irritating force, or by the injury of a motor-nerve trunk, the muscles passing over the fracture or in the vicinity of the fracture tend to spasmodic contraction. This is observed especially in the limbs, and more particularly about the humerus and femur, in which it almost invariably causes an overriding of the fragments.

Shortening of the Limb.—By this is understood the shortening caused by such overriding as that described above, by impaction, or by loss of substance.

General Immediate Symptoms.—*Depression.*—This depends upon the presence of injury or disease in other organs, upon the mental condition of the patient, and upon the degree of hemorrhage and injury to the nerves.

Shock.—This is an exaggerated form of general depression. It depends upon the same etiological factors, and is rarely observed except in cases of multiple fractures, or fractures with severe laceration of soft tissue or with injury to other organs.

These general symptoms are scarcely perceptible in the ordinary forms of fracture. The mediate or later symptoms of fracture may also be divided into local and general.

Local Mediate Symptoms.—In the course of a few hours there

always develops about the seat of fracture more or less *edema*. There may also be present edema of the whole limb below the fracture, as the result of obstruction to the return circulation by pressure upon the vessels by fragments or edges of bone, by angulation, or by the perivascular exudate. When the exuded serum comes to the surface, it lifts up the outer layer of the skin and forms the blebs or bullæ which are common about fractures.

Ecchymosis is one of the most constant symptoms. It appears a few hours after the injury as a mottling of the skin, varying in color from a pale olive or red to a dark maroon or bluish tint. The blood comes from the broken bone and from the torn soft tissues. The natural tendency is for the pain and tenderness to subside, although it sometimes happens that, as a result of the pressure of the exudate, these symptoms become aggravated. Local rise of temperature accompanies the increase of blood-supply and the increased metabolic changes.

General Mediate Symptoms.—*Fever* develops to a greater or less degree in all fractures. Hemic or aseptic fever is present in all cases, and is due to the liberation of fibrin-ferment from the extravasated blood, and the reabsorption of the same. The duration of this fever depends much upon the amount of the extravasation. It is accompanied with no evident constitutional disturbances. Septic fever depends upon the presence of infective organisms, and belongs to the consideration of wounds.

Diagnosis.—Though usually the diagnosis of fracture is not difficult, it happens in many cases that the skill of the surgeon is taxed to decide as to the existence of a fracture, its location, or its variety. The diagnosis should be based first upon the history. In this is considered the question of predisposing and exciting causes, particular inquiry being made as to the character of the injury. The symptoms should next be considered. In many cases the discovery of a false point of motion and crepitus cannot be made, because of the extreme tenderness or strong muscular spasm. These obstacles are eliminated under general anesthesia. To elicit these symptoms the limb should be firmly grasped by the two hands close together, one above and the other below the fracture, and the lower fragment moved upon the upper by either transverse, rotary, or angular motion. When a fracture is near a joint, the motion of the joint may be confused with the false point of motion. By fixing the head of the bone and moving the other fragment the fracture may be discovered. True bony crepitus should not be confused with intra-articular grating due to chronic roughness or recent injury of the joint-surfaces, or with the crepitus of inflamed bursæ or tendon-sheaths. Deformity due to rupture of muscle or to local effusion of serum or blood following injury often simulates the appearance of fracture, and when such deformity is associated with pain and tenderness the diagnosis must be made by seeking for the bone-injury. Although pain may be due to the contusion, still when it is distinctly and narrowly localized, and especially when manipulation at a distance from the seat of injury causes pain in the same narrow area, the probability of the presence of fracture at that point is very strong. In certain fractures these peculiar symptoms are not

present because of the inaccessibility of the seat of fracture. This is the case, for example, with fracture of the base of the skull.

In the diagnosis of fractures a knowledge of the landmarks, and especially of the bony prominences about the joints, is of great importance. The presence of deformity and its degree may be determined by comparison of the injured limb with the sound limb, and by measurement of the bony prominences on either side of the injury. The rational signs are determined by palpation and inspection. By applying the stethoscope firmly over the injured bone, and applying percussion, the percussion-note will be distinctly heard so long as there is no solution of the continuity of the bone between the stethoscope and the point of percussion; but if a fracture intervenes, the sound-wave is lost. Finally, a shadow-picture of the bone may be obtained by means of the Rōntgen process.

The healing of fractures is discussed elsewhere.

Treatment.—The treatment of fractures is based upon two fundamental principles—the correction of the deformity, and the maintenance of the fragments in normal apposition until consolidation has taken place.

The methods of replacing the fragments in their natural positions must naturally vary much with the location and character of the fracture. In many fractures there is little or no displacement whereas in others the displacement amounts to a complete separation of a part of the bone to such a degree as to cut it off from vital connection with the rest of the body. Simple fractures of the leg without displacement are often changed into fractures with displacement, or even into compound fractures, by the patient attempting to use the leg immediately after the accident. It is no uncommon occurrence for simple fractures to be converted into fractures of the compound variety by a sharp point or edge of bone penetrating the skin during the manipulation of the limb or while the patient is being transported. It is therefore important that the greatest care be exercised to prevent the injury from being made worse. A fractured limb should be kept as still as possible until the fractured region can be exposed. Trousers-legs, drawers, shoes, and stockings should be cut off, if their removal otherwise cannot be accomplished without undue moving of the injured limb.

In the case of a complete fracture of the bones of the leg or thigh, when the limb is moved, it should be supported both above and below the seat of fracture, and grasped in such a way as to prevent rotation as well as angular motion. When the patient is to be moved from the seat of the accident, motion of the fragment may be prevented by extemporized splints of board, straw, rolls of paper, cloth, twigs, or the injured limb may be bandaged to its fellow with a pillow between. The patient should be carried, if possible in the recumbent position, on a litter. The subsequent treatment should be conducted upon a hard bed—that is, a bed with a firm mattress, which does not sag with the weight of the body. To accomplish this, boards should be placed between the mattress and the springs of the bed.

In the correction of the deformity or the setting of the fracture the force should be applied gently, increasing firmly and gradually, not quickly and abruptly, until the desired result is secured. When there

is simple lateral displacement, the limb should be grasped firmly by the left hand above and by the right hand below the fracture, and, as steadily increasing traction is applied, the lower fragment should be slipped over into place. The same course of applying extension should be pursued in correcting fracture with overriding and with rotary displacement. When the muscular resistance to the correction is still greater, an assistant should make counterextension above, and steady the leg while the surgeon with both hands applies traction and correcting manipulations. In correcting angular displacement, whether the fracture be complete or of the green-stick variety, extension should be employed at the same time with the lateral force which overcomes the angulation. The deformity of impacted fracture is overcome by direct extension.

Ordinarily, the reduction of fractures is simple and satisfactory, but there are certain obstacles which may intervene. The muscular contraction may be so strong that it resists the combined efforts of surgeon and assistant. A second obstacle to correction is great pain. These two symptoms may be overcome by the use of general anesthesia. When general anesthesia is employed, the splint-material should be at hand, and the immobilization of the bone should be accomplished while the patient is still under the influence of the anesthetic. Tenotomy, or the subcutaneous division of resisting muscle, may be employed to facilitate reduction. A third obstacle to reduction is the interposition between the bone-fragments of muscle, clot, periosteal tissue, loose fragments of bone, or a foreign body. When a satisfactory reduction cannot be effected because of these things, the seat of fracture should be exposed and the obstacle removed. It should be borne in mind, however, that if no infection is present, none of these obstacles, with the possible exception of a foreign body, will actually prevent the osseous union of the fragments, although they will retard it, for they are all capable of becoming involved in the callus and incorporated in the bone-tissue. One of the great objections to their presence is the fact that they render perfect immobilization more difficult, and thus conduce to non-bony union. This is observed, for example, in the transverse fracture of the patella, in which the interposition of clot and torn periosteum absolutely prevents bony union. A final obstacle to correction is impaction, which may be so firm that it can be overcome only by great force. When this is the case, if the impaction is not broken up, solid bony union is assured; but the surgeon should always have as his guide in the treatment of fractures the idea of the restoration of the parts as nearly as possible to their normal state.

The reduction of fractures should be attempted as soon as possible after the accident. Every hour's delay increases the firmness of the plastic effusion about the seat of the fracture, and renders reduction more difficult. If a fracture with overlapping has been allowed to go uncorrected, the infiltration with exudate of the surrounding tissues so destroys their elasticity that reduction without operation may be impossible; nor may the surgeon expect to overcome this resistance by general anesthesia.

Before proceeding further with the treatment, the condition of the skin should be looked to. Excoriations should be covered with mild

antiseptic ointment spread upon dry gauze. Serous blebs should be snipped with scissors at their most dependent part, and all of the fluid evacuated. The cuticle need not be removed, but should be covered with a bland powder, such as zinc oxid, and a few layers of dry gauze. The surface should be examined for prominent points of bone beneath the skin, which might penetrate and render the fracture compound. If such a point is discovered, further manipulation should be resorted to with the view of securing a more perfect reduction. When this cannot be accomplished, the danger may be lessened by applying a compressing pad of gauze. Care should be taken that the compression is made not directly upon the threatening point, but over the neighboring bone with which it is connected. No encircling bandage should ever be applied next to the skin beneath a splint, unless the rest of the limb beyond is completely covered by bandage equally firm.

The immobilization of the fragments is accomplished by one of the following means: By position, by splints, by extension, or by direct fixation. In certain cases, however, the deformity remains corrected without the use of any of these artificial methods. The placing of the parts in a certain position—as, for example, the use of the double inclined plane in fractures of the leg, or the dorsal recumbent position of the body in fractures of the clavicle—often suffices to retain the bones in the desired apposition.

Before the application of a permanent splint, the parts to be covered should be cleansed with soap and water. As a general rule, it is well to immobilize the joints immediately above and below the fracture. The greatest care should be taken to avoid local pressure by the splint-apparatus. Pressure should be evenly distributed. Prominent points which may receive undue pressure from the splint should be thickly covered with soft padding. A splint which has been properly applied should give to the patient a feeling of comfort and support to the part. The persistent continuance of pain means that something is wrong, and the splint should be removed.

Of the materials used for splints, the most valuable is plaster of Paris, the introduction of which has marked an era in the treatment of fractures. In most cases it is best employed in the form of the plaster bandage. This consists of a roller bandage of coarse-meshed cotton cloth, in the meshes of which dry plaster is held. These bandages are made by drawing the strip of bandage through the plaster, and loosely winding it, so that when the bandage is completely rolled there is a rich amount of plaster between its folds and held within the meshes of the fabric. These bandages may be made in any width, but preferably from 2 to 4 inches (5 to 10 cm.). Plaster of Paris absorbs water from the atmosphere in the course of time, and when slightly hydrated in this way does not harden well. Unless the plaster has been protected from the air by keeping in a tightly sealed receptacle, it should be subjected to dry heat before using. When the bandages are kept already made up, they may be dehydrated by placing them in the dry heat of an ordinary kitchen oven. When ready for use the roller bandage should be put in sufficient water to cover it, the bandage standing on end to allow the bubbles of air to escape. After having become thoroughly hydrated, the excess of water should be squeezed out,

the ends of the bandage being covered by the hands to prevent the escape of the plaster. It is usually desirable that the plaster harden as quickly as possible. To facilitate this, hot water to which salt has been added, an ounce to the quart of water, should be used.

Before applying the plaster bandage, the skin should be smoothly and evenly covered with cotton wadding or flannel bandage. If the person applying the plaster is skilled in its use, the best covering for a limb is a seamless white cotton stocking, upon which the plaster may be directly applied. In the case of an ordinary fracture of both bones of the leg, the skin having been cleansed and covered, the patient should be placed upon a narrow table; the assistant, standing on the side opposite the surgeon, grasps the foot firmly in his right hand, while the left hand supports the leg at a point just above the seat of fracture. The desired position having been secured, a plaster bandage 4 inches (10 cm.) wide is applied about the leg at the seat of fracture, gradually extending above and below as far as the knee- and ankle-joint. A narrower bandage may then be applied to the foot and ankle, and extending up over the fracture. This should be followed by a wide bandage involving the leg and extending up over the knee. After this the bandages may be continued until the desired thickness has been secured. By applying some long spiral turns or a few longitudinal strips, and by rubbing well together the layers as they are applied, the degree of firmness of the splint may be much increased and the amount of material required diminished. The greatest care should be taken that the pressure made by the dressing is even. The bandage should always be applied perfectly flat, and not with one edge drawn more tightly than the other. The splint may be strengthened by incorporating in it strips of wood-shavings, wooden splints, or strips of wire gauze or thin metal.

A substitute for plaster of Paris is silicate of soda. Bandages impregnated with a solution of this material, after they are once hardened, are not softened by moisture. The disadvantage is that it makes a less firm dressing than the plaster. When it is desired to render a plaster splint impervious to water, it may be coated with a solution of silicate of soda or with varnish.

Moulded splints are made of soft materials which harden after having been pressed against the part and made to conform to the desired shape. For this purpose several layers of fabric, cut to the desired length and width, and impregnated with a solution of plaster of Paris while in a pliable state, are pressed against the limb and held in place by a bandage or by straps. Papier-maché and felt are also used in this manner. Splints of this sort are usually made in the form of a gutter, so that they may be removed at pleasure. The complete plaster-bandage envelope may also be converted into a removable or a gutter-splint by cutting it into two parts by means of an anterior and a posterior incision or by lateral incisions. One or both of these parts may be used; or they may be united, corset-like, by laces and hooks.

Non-plastic splints are made of wood and metals. Of the former are the thin elastic strips of soft wood, called coaptation-splints, and the heavier straight splints. The fracture-box, which used to figure prominently in surgery, has quite gone out of use. A great variety of metal-

lic splints are made for the special fractures; but plaster of Paris can be used in the place of most of these. The ambulatory splint for the treatment of fractures of the lower extremity is described elsewhere.

When the tendency to overriding of the fragments is persistent, the application of permanent extension becomes necessary. This is accomplished by attaching a weight to the extremity, by elastic extension, or by using the weight of the limb itself to overcome the deformity. The methods of applying extension will be described in treating of the special fractures.

In certain cases, despite the best efforts, the fragments cannot be made to remain in satisfactory apposition. When all other resources have failed, the well-equipped surgeon is justified in exposing the seat of fracture and applying such local treatment as the conditions require. The incision of operation often liberates an amount of blood and serum, the presence of which has been an obstacle to reduction. The removal of soft tissues which have fallen between the bone-ends can then be accomplished. Often nothing further is required. But when the surgeon feels that neither splints nor extension will suffice to hold the fragments in place, he should proceed to the direct fixation of the bone-ends. Direct suturing or binding of the bone-ends by means of wire,

FIG. 217.—Fracture of tibia immobilized by clamp-and-screw apparatus (Parkhill).

silkworm-gut, or chromicized gut is often indicated. Nails and pegs of bone, ivory, or metal may be used; or bone or metallic plates, or bone ferrules or cylinders; or external metal plates controlling the deeper bone fragments by long screws, as in the method of Parkhill (Fig. 217).

Bircher has introduced a cylinder of ivory into the medullary canal for the purpose of preventing lateral displacement; and with the same view, Senn has used a hollow perforated bone-cylinder. Senn has advocated the use of ferrules made from the tibia and femur of the ox for holding oblique fractures in position. The overlying wound is closed and the foreign material allowed to heal in. When metals are used, they may be exposed and removed at a later operation. In the case of simple wire sutures, the ends may be left long enough to project through the wound, which is closed throughout and covered by copious dressings. With the ends as a guide, the wire may be cut and easily removed after it has served its purpose.

In dealing with comminuted fractures with irreducible displacement, after extension, manipulation, anesthesia, and tenotomy have failed, the same general principles, stated above, apply. Here the surgeon often has to do with loose fragments of bone which have become entirely separated, and often so displaced as to form the chief impediment to

reduction. Such fragments should usually be removed. If replaced and allowed to remain, their tendency is to become exfoliated, though this tendency is being overcome by the perfection of surgical technic. After the removal of a large fragment of bone from the leg or forearm, the parallel bone prevents the bone-ends coming together. In such case an equal amount may be resected from the sound bone, if the amount of bone required to be removed is not so great as to destroy the usefulness of the muscles. When the gap is too great to be thus treated, it may be filled with bone from a foreign source, or treated by an osteoplastic lengthening of the injured bone.

The involvement of a joint by a fracture adds another element of importance. As a result of the injury to the joint, there is an intra-articular effusion of blood and serum, and the traumatic reaction about the line of fracture causes the formation of plastic exudate upon the synovial surface. For this reason, ankylosis, due to the adhesions of the new-formed plastic exudate to the opposing synovial surface, is prone to develop when the joint is kept immobilized for any considerable time. Moreover, motion of the joint immediately after the injury increases the amount of exudate and effusion, and thus increases the liability to ankylosis. The guiding principle, therefore, in the treatment of such fractures, is immediate and complete immobilization, and thereafter, carefully applied passive motion as soon as the traumatic reaction has subsided, and the consolidation of the fracture has become sufficiently advanced to hold the fragments securely together. The early application of the ice-bag will diminish the effusion of fluid into the joint. Evenly applied pressure by means of a flannel bandage has the same effect, but is less desirable during the first few days. Later, at the end of one or two weeks, when the acute reaction has subsided, massage, heat, and pressure will hasten the removal of the effused fluid. If the amount of fluid is very great, or if these methods fail to cause its absorption, the joint must be aspirated, or incised and cleaned out if the distention is due to blood-clot. When immobilizing such a joint, the surgeon should always have in mind the possibility of the danger of ankylosis; and, when consistent with the treatment of the fracture itself, he should place the joint in such a position as shall render the limb the most useful should this untoward result occur. Ankylosis should later be overcome by carefully applied passive motion.

The treatment of compound fractures is based upon the same principles as govern the treatment of wounds, plus the principles which have already been laid down for the treatment of fractures. Some of the salient points of these two conditions may be briefly mentioned. If a temporary dressing is to be applied, the wound should be irrigated by introducing between its lips an irrigating point and washing it out with a 1 : 2000 sublimate or other antiseptic solution. Over this should be placed a copious moist dressing of gauze wrung out in the same solution, followed by the temporary splint. After the patient has been removed to the place for further treatment —preferably the hospital operating-room—and placed upon the table, the region about the wound should be exposed widely. In the more severe cases requiring considerable manipulation, it is best to administer

a general anesthetic before the temporary splint is removed. If the fracture is one of the leg, it should be rested upon a sand-bag, which can be made to conform in shape to the posterior contour of the limb. The surrounding field should be covered with sterilized towels. A bit of gauze should be held against the wound while the whole leg is thoroughly scrubbed with soap and water, shaved, and, especially the region just about the wound, cleansed with ether and a 1 : 1000 solution of sublimate. The wound should again be thoroughly irrigated with antiseptic solution, and its extent and the character of the fracture explored.

If the injury to the soft parts is but slight, the displacement of bone inconsiderable, and the amount of hemorrhage and effusion small, the wound may be partly sutured, leaving always a liberal opening for drainage. Into this may be introduced a strip of sterilized gauze, and the whole covered with a moist sterile gauze compress. In no case is it recommended to seal the wound of a compound fracture hermetically.

Should the examination show that there is considerable injury to the soft tissues, irreducible displacement, or the presence of foreign matter, the surgeon should freely enlarge the wound, or make such new wounds as shall give the best access to the seat of injury. There should be no timidity in multiplying the number of longitudinal wounds, for in these cases abundant provision for drainage is most desirable. It often becomes necessary to repair ruptured muscles, tendons, and nerves, or to ligate blood-vessels. All foreign material should be removed with most scrupulous exactness, frayed and damaged bits of fascia and muscle should be cut away, and loose fragments of bone should be removed, the bone being dealt with, if necessary, by the methods of direct fixation described above. In closing the wounds, the provisions for drainage should be abundant. It is well in these more severe cases to apply a large absorbent dressing, and immobilize the bone by a temporary splint. At the end of four or six days—sooner or later, varying with the degree of the patient's temperature and other signs—this splint should be removed and the wound dressed. Drainage-tubes should be irrigated through and through to insure their patency, and gauze drains should be renewed or removed. From this time on the surgeon should be guided in the dispensing with drainage, in the shortening of drains, in the instituting of new drainage, in the application of secondary sutures, and in the management of the wound by the general principles for the treatment of wounds.

At as early a stage as possible a permanent splint should be applied, with suitable provision for dressing the wound without removing the splint. A small dry dressing, quadrilateral in shape, having been applied, and the dressing covered with the impervious oiled muslin of the shops, the plaster cast should be put on over all. Before the plaster has become thoroughly hardened, a fenestrum, outlining the dressing, should be cut. The oiled muslin should then be cut through and reflected back over the four edges of the fenestrum in such a way as to prevent the moisture of the dressings softening the plaster.

If more than one fenestrum is required, or if the fenestrum must involve more than half of the circumference of the splint, it should be strengthened by incorporating into it a strip of basswood or a metal

bar. The same end can be accomplished by introducing an iron bar which passes down as far as the fenestrum and then leaves the plaster bandage and curves over the opening to re-enter it below.

Three conditions arising in compound fractures justify immediate amputation—injury to the blood-vessels so great as to cause the death of the part, uncontrollable suppuration, and wide loss of bone-substance. It is often evident at the first examination that the injury to the vessels has been so great that the parts below the wound must become gangrenous. In such cases the extremity is found to be cold and to present a gradually increasing livid color. The main vessels may be found to be divided or thrombosed. Pressure upon the skin or nails does not show the return of blood into the capillaries of the area from which it was expressed. In such cases amputation should be done. On the other hand, examination may show the extremity to be cold and the main vessel pulseless, but if all the signs of death of the part are not present, the surgeon should endeavor to save the limb, inflicting, as he proceeds with the examination and dressing, the least possible traumatism, and, finally, applying the bandages as loosely as possible. In all cases an effort should be made to preserve the extremity, unless it is unquestionably beyond saving. Nor even then is immediate amputation always called for. If the patient is suffering from shock, extreme depression, or anemia, or if other conditions are present which render the continuation of operative procedure extra-hazardous, the parts should be thoroughly cleansed, hemostasis secured, a large, moist, antiseptic dressing applied, and further operation deferred. If circular compression is used to control the hemorrhage previous to amputation, it should be applied as low down as possible, preferably directly over the wounds, as the vitality of the tissues below the pressure is greatly impaired, and flaps involving such tissue are prone to slough.

When in a compound fracture, notwithstanding free and wide incisions, abundant drainage, and irrigation, because of some constitutional or local condition, uncontrollable suppuration persists, and septicemia threatens the life of the patient, amputation well above the suppurating area should be performed. The same operation is necessary when, through local disturbance to the blood-supply, suppuration causes a gangrene of the extremity. Amputation is also indicated in cases in which there is so much destruction of bone that, in order to bring the bone-ends together, the limb must be shortened to such a degree and the soft tissue so folded as either to render the limb less useful than an artificial substitute, or to give rise to gangrene because of obstruction to the circulation through angulation of the vessels. In cases such as this an effort should be made to save the limb by means of an osteoplastic operation or by the transplantation of bone to fill the defect. Among the greatest triumphs of modern surgery are the saving of limbs which are the seat of a compound fracture.

Although every effort should be made in the line of conservative surgery, still there is a fourth class of cases in which amputation is indicated. These are the cases in which, in order to preserve the limb, a very long and trying period of treatment must elapse, with continuous suppuration and confinement, all of which must have a depressing

effect upon the health of the patient, and end in securing only an imperfect limb. The age, sex, and occupation of the patient, the location of the injury, and the adaptability of prosthetic apparatus to the particular part, should be taken into consideration; and, finally, with a full understanding of the case, the patient himself may be called upon to elect the course which shall be followed.

Complications.—By the complications of fracture are understood the less characteristic symptoms, or the rarer conditions which may arise, but which do not occur with sufficient frequency to be regarded as symptoms.

Immediate Complications.—Comminution, impaction, and dislocation may be mentioned as complications. Injuries to the soft parts—muscles, viscera, vessels, and nerves—often demand special treatment. Lacerated muscle often requires suturing; pulpified muscle should be cut away. Injuries to the viscera, such as the brain in fractures of the skull, and the bladder in fractures of the pelvis, are dealt with according to rules laid down elsewhere. Large blood-vessels are frequently lacerated either by the force which causes the fracture or by a sharp edge of bone from within. Such laceration may give rise to an extensive effusion of blood into the tissues, showing itself in the form of swelling and discoloration or localized hematoma. If the swelling is considerable, or if the pressure from the extravasated blood is so great as to hinder the circulation materially in the limb beyond, the vessel should be exposed and the bleeding point ligated. Traumatic aneurysm and aneurysmal varix are thus sometimes associated with fractures. Laceration of lymphatic trunks causes a localized lymph-edema which may require surgical treatment. The pressure of displaced bone against the vessels may impede the circulation to such a degree as to threaten gangrene. Injury to the nerves at the time of fracture is no uncommon complication. It may be in the form of laceration, compression, or stretching of the nerve. All of these are accompanied with pain and more or less disturbance in the parts beyond. If paralysis is present, and the traumatism has been great enough to have caused laceration, though the examination shows no evidences of pressure as a cause of the paralysis, the surgeon is justified in exposing the nerve with the view of discovering the character of its injury, and suturing the ends if laceration is discovered.

Mediate Complications.—The mediate or later complications are those which may come on any time during the process of healing. They constitute a large catalogue of widely different conditions.

The pressure from the effusion of serum may be so great as to obstruct the circulation to such a degree that gangrene of the parts beyond is threatened. Such extreme swelling may be relieved by multiple longitudinal incisions, allowing the serum to escape, followed by elevation of the limb. After a limb has been bandaged for a long time, edema is observed on the removal of the bandage because of the vasomotor paralysis. The vessels gradually regain their tone, however, and the swelling subsides. Usually the edema due to fracture does not call for any special treatment. The firmly and evenly applied bandage from the toes or fingers up usually suffices to control the swelling. The sooner and the more firmly a fracture is immobilized,

the less will be the swelling. This is a rule which the surgeon should always have in mind.

Inflammatory swelling is amenable to the treatment described elsewhere. Ulceration, sloughing, and gangrene, due to the constriction of bandages or pressure of splints, are dangers always to be guarded against. Dressing materials should never be wound circularly about a limb, but should be applied lightly in folds or longitudinally. The bandage which holds the dressings should never be tighter than the flannel bandage beyond. The tips of the fingers and toes should always be left exposed, in order that the condition of their circulation may be observed. It should always be borne in mind that the shock which a fractured limb has received has diminished its vitality. Patients suffering with diabetes are especially liable to gangrene following fracture, as are those with atheromatous vessels and cardiac disease. When gangrene appears, the surgeon should determine its cause; and when this is not removable, the further treatment must depend upon the absence or presence of infection. Thrombosis occurring in a large vascular trunk, as the result either of traumatism to the inner coat of the vessel or of inflammation extending thereto, is a prolific cause of gangrene. Thrombosis occurring in a vein may be the cause of edema or of gangrene.

Fat-embolism is a condition peculiar to fractures, and comes on about the third day. It is due to the liberation of fat from the medulla of the broken bone, its entrance into the torn veins, and its transmission through the circulation to the various organs of the body. Aggregations of globules of fat are found plugging capillaries of the lungs, brain, kidneys, and other organs. So long as the infarctions thus produced are not infective, or do not shut off the blood-supply from any considerable part of a vital organ, as is usually the case, the occurrence is of little moment. Rarely, however, a cerebral vessel of considerable size or a large number of smaller vessels thus become obstructed, and the patient dies usually about the fourth day. It is probable that in every fracture some fat enters the circulation. The cases with severe comminution are those in which the condition is most apt to be of a serious character. Dyspnea, Cheyne-Stokes respiration, and the signs of cerebral embolism have been observed in these cases. *Blood-embolism* originates by a thrombus being swept loose from a vein at the seat of fracture, carried to the heart, and thence thrown into the pulmonary circulation. In the cases in which this accident has occurred, the first sign was the sudden appearance of extreme dyspnea about the third week after the injury. When the embolus has been large enough to plug a pulmonary trunk of considerable size, the patient has died a few moments after the attack began.

Muscular spasm, which has already been spoken of among the symptoms of fracture, often persists during the period of treatment, and requires to be overcome by constant traction or some of the methods described above. Other complications are acute osteomyelitis and suppurative osteitis. *Necrosis of bone* is a common complication in compound fractures. This is often manifested in the form of a superficial exfoliation of thin plates or spicules of bone. Two

conditions usually contribute to this—denudation of the bone of periosteum, and the presence of suppuration. Sometimes the necrosis involves the whole thickness of the bone; often the two ends of the fragments become exfoliated. When it is evident to the surgeon, from the white appearance of an area of bone, from its failure to give rise to granulation-tissue or to become attached to the surrounding structures, that a particular part of the bone has become devitalized, he may know that the wound which is connected with it will continue to discharge until the dead portion has become exfoliated by the slow natural processes or until it has been removed by artificial means. In order to hasten the healing in such cases, the diseased bone may be chiselled or sawed away until healthy bone, as evidenced by the color or by the bleeding, is exposed.

Stiffness of joints occurs as a result of prolonged immobilization, involvement of the joint in the fracture, or from extra-articular mechanical causes. The time required for a joint to regain its suppleness after prolonged immobilization varies greatly with different circumstances. At the best it is always a matter of considerable time, and is greatly delayed in the case of old and rheumatic persons. The general rule of liberating joints from confinement by shortening or removing splints as soon as possible should be followed. Gradually applied passive and active motion should be instituted in all cases as early as the other conditions will permit. In this, massage is a most valuable measure. *Atrophy of the limb* occurs in all fractures involving these members, chiefly as the result of disuse. From this cause it often happens that a plaster bandage which at first was snug becomes so loose that it is no longer adequate for the perfect immobilization of the limb. The atrophy involves not only the muscular tissue, but the connective tissue as well, and the diminution in the blood-supply, and hence the lessened amount of fluid in the limb, makes the atrophy seem even more pronounced. When the limb is again brought into use, the atrophy gradually disappears. The affected tissue may be more quickly restored to its normal condition by the application of massage. *Pain* about the seat of fracture or along the distribution of a nerve may be a continuation of that symptom, or it may be due to the involvement of a nerve in callus or in inflammatory exudate, or to the pressure from some of the above-described pressure-producing conditions. *Paralysis of muscles* below the fracture is due to the same causes. The treatment consists in relieving the nerve from pressure. Often this can be accomplished only by cutting down upon the nerve and freeing it from the compressing tissue, or by removing the bony prominence which may be pressing against it.

Excessive callus or *excessive new connective-tissue deposit* is a condition resulting from imperfect immobilization or severe comminution. It is often found about the femur and humerus, because of the difficulty in thoroughly immobilizing these bones. It is brought about by the repeated breaking and straining of the newly formed circulatory channels. As a result of these traumatisms, new plastic material is poured out, and the surrounding muscles, and even tendon-sheaths, nerves, and vessels, become infiltrated with young connective-tissue cells. The swelling and induration thus produced often give rise to the suspicion

of malignant tumor developing at the seat of fracture, and microscopic examination of such tissue requires very careful study to differentiate it from certain forms of small round-cell sarcoma. The healing of a fracture of the femur, for example, may have progressed to a state of apparently satisfactory consolidation; the patient is allowed to use the limb prematurely; he complains suddenly of pain and a feeling of weakness in the affected part; swelling about the callus begins, and in the course of a few days the callus seems to have become greatly enlarged. This is the picture of re-fracture or giving way of a poorly consolidated callus, with the subsequent pouring out of an excessive or compensatory plastic exudate. Here again the statement may be made that the more perfect the immobilization of a fracture and the sooner immobilization is applied, the less will be the swelling.

Certain *morbid growths* appearing at the seat of fracture may be classed as complications, although usually such developments take place after full consolidation has been reached. It has been shown that sarcoma of bone frequently has its beginning at the seat of an old or recent fracture. *Arthritis* and *tendosynovitis*, either traumatic or infective in origin, are to be classed among the complications. *Shortening of the limb* can be the result of overriding, of impaction, of loss of substance, or of developmental defect following the separation of an epiphysis. All the complications of wounds, including especially suppuration and tetanus, are among the complications of compound fractures. *Surgical emphysema* results from the entrance of air or gas into the connective-tissue spaces. It is usually found associated with a fracture in which there is a wound of the lung, or of some part of the respiratory tract, or in the region which shares in the respiratory movements. Air thus admitted penetrates the loose subcutaneous connective tissue, and may extend over a large area of the body, giving a peculiar crackling and crepitating sensation upon pressure. Certain gas-producing micro-organisms cause a similar phenomenon after gaining access to a wound.

Hypostatic congestion of the lungs, bed-sores, inhibition of the function of the excretory organs, suppression of urine, retention of urine, are complications commonly found in old or debilitated persons. These are the special dangers which threaten the old, and render confinement in bed a matter of great hazard. In such cases every effort should be made to carry on the treatment in such a way that the patient may not be kept constantly in the dorsal-recumbent position. It is much better surgery to be satisfied with a less perfect local result, and preserve the patient, than to allow technical zeal to strive for a perfect cure of the fracture at the cost of the patient's life.

Delirium tremens is prone to occur in persons who have habitually taken alcohol, and who for some reason are compelled to remain for a considerable length of time in the recumbent position. *Traumatic delirium* or *delirium nervosum* is a condition of nervous excitement following injuries observed in neurotic persons. *Crutch-paralysis* is one of the later complications. It arises from the pressure of a crutch upon the nerves in the axilla, producing paralysis of the muscles of the arm.

Besides the immediate and mediate complications, there are certain

later complications which are observed after the fracture has united and treatment has been discontinued. The gradual appearance of deformity at the seat of fracture, resulting from instability or softening of the callus, requires reimmobilization or treatment for faulty union. Persistent atrophy may be due to continued disuse, nerve-disease, circulatory disturbance, joint-ankylosis, or to retarded development subsequent to the separation of an epiphysis. Neuralgia sometimes persists as the result of pressure upon a sensory nerve or infiltration of the nerve with new connective tissue.

Faulty or **vicious union** results from the absence of treatment of fractures, or when consolidation has been allowed to take place with the fragments not in normal apposition. It may occur associated with any of the forms of displacement. The usefulness and symmetry of a limb may thus be greatly impaired, and symptoms arising from pressure upon vessels and nerves may be produced. If the deformity is near a joint, the function of the joint is impaired. If the deformity is but slight, the impairment of function inconsiderable, and the patient satisfied with the result, no treatment need be urged. In the more extreme cases the bone should be refractured, the deformity corrected, and the treatment of the fracture begun anew. Within the first few weeks the refracture of a bone with angular deformity is a simple matter; but when the fracture is old, or situated near a joint, or has healed with overriding, great care is required. The bone may be broken by simple manual force; but it is well to bind splints firmly to the limb above and below the point where it is desired to make the break, in order to localize the strain. The bone should be broken by a quick, strong force, rather than by a gradually increasing force. The instrument known as the osteoclast may be used with advantage in some cases. The most exact treatment is by osteotomy. This may be done by a subcutaneous operation in the more simple cases, or by the open method in cases with overriding of the fragments. It often becomes necessary to resect a portion of the bone before a perfect reposition can be accomplished.

Delayed Union.—The term delayed union is applied to those cases in which, though the processes which bring about union are going on, the production of ossification in the callus is slow. It is a retardation of the reparative process, whereby the bone is united by unossified or imperfectly ossified connective tissue or callus. Imperfect immobilization, too early mobilization, overriding, and separation of the fragments are important etiological factors. Local inflammation in compound fractures is a common cause of delayed union. It may be due to certain constitutional disturbances, such as the slow production of plastic material at the seat of fracture from local or general nutritive defects, or to the slow ossification of the callus from a poverty of lime-salts.

The treatment of delayed union consists first in removing any discoverable cause. The local nourishment should be improved by increasing the blood-supply. This may be done by improving the patient's general condition. The fracture being perfectly immobilized, the patient should be encouraged to go about as much as possible. The local blood-supply may be increased by irritation. This is accomplished by

hammering the region of the fracture each day with a padded wooden hammer or with a hammer of paraffin or wax. The application of the electric current is of questionable value. Blistering and cauterization over the fracture are of very little value. Good results are secured by driving into the bone-ends pegs of bone, which are allowed to remain *in situ*. The bones may be bored or punctured in several places without leaving in any pegs. A most valuable means of arousing hyperemic reaction is to break asunder forcibly the fibrous attachment by flexion and rotation, followed by rubbing the bone-ends together. This should be done under general anesthesia. If necessary, the operation should be repeated till pain, tenderness, and considerable swelling have appeared. Another plan is to drive the bone-ends forcibly together to the degree of producing impaction. After sufficient irritation has been produced by these measures, the limb should be thoroughly immobilized. Six months is not too long a time to give to securing consolidation.

Fibrous or **ligamentous union** consists in the connection of the bone-ends by means of unossified fibrous connective tissue, which permits more or less motion between the fragments. It is unremedied delayed union, and may be due to any of the causes which produce delayed union. The interposition of soft tissue, such as muscle, fascia, and blood-clot, between the fragments is one of the most prolific causes of this accident. When the treatment for delayed union has been unsuccessful, and when there seems to be no tendency to ossification, or if, for some reason, a more speedy and certain cure would be arrived at, more radical operative measures are justified. The bone should be cut down upon, the intervening tissue removed, the fragments freshened by sawing off the ends, and the freshened bone-surfaces brought together. It is often found that the bone near the fracture has become atrophied and porous. When this condition exists, the periosteum should be stripped away from the bone, but left attached to the surrounding tissue; the most softened part of the degenerated bone should then be cut away. It sometimes occurs that there is so great a destruction of bone that a considerable space is left. It may be necessary to fill this by an osteoplastic operation, or by the transplantation of bone. Finally, there are cases of old fibrous union in which the very slight motion does not materially impair the usefulness of the limb. These cases need no treatment.

The constant rubbing together of the fibrous covered ends of the bones sometimes results in the formation of a bursal sac between the fragments. Thus a new joint is formed, in which the connective tissue, representing the unossified callus, forms the capsular ligament. If operative treatment is indicated, the new joint-sac must be removed, and the treatment proceeded with upon the lines laid down above.

Non-union is a comparatively rare condition in which little or no reparative action has taken place. In this, the bone-ends are found not connected by any new-formed tissue whatever, but lie free in the surrounding soft structures without having excited any reparative, exudative reaction. It may be due to the causes which contribute to delayed union and fibrous union, but is more dependent upon malnutrition. The treatment is the same as that for delayed union, followed, if necessary, by the treatment which is applied for ligamentous union.

Intra-uterine fractures are of surgical importance chiefly from the standpoint of vicious union and developmental defects. They are due to traumatisms to the child-containing uterus and to uterine contractions. The predisposing causes are syphilis, osteitis, malnutrition, and malformations.

SPECIAL FRACTURES.

The Nose.—The projecting bony and cartilaginous framework of the nose is the frequent seat of fracture, caused by the direct violence of blows received by it or of falls upon it. The damage sustained may be of every degree of severity, from simple diastasis and deflection of the cartilaginous septum, or fracture of the thin projecting edge of a nasal bone, to much comminution and marked depression of the whole bony arch, with fracture of the perpendicular and cribriform plates of the ethmoid. While the more serious and extensive injuries are usually recognizable on sight by the marked deformities which they produce, the slighter injuries are not infrequently overlooked, being masked by swelling of the overlying soft parts; and not till after this has subsided is it appreciated that consolidation of malposed fragments has already occurred, with permanent deformity. As early as possible, therefore, careful examination should always be made of the whole framework of a nose which has been subjected to violence, to detect and remedy any displacement that may be present, since even slight deviations from its normal contour or direction inevitably produce notable permanent disfigurement, and unrelieved deviations of the septum not only entail deformity of the nose, but may lead to subsequent chronic disease of the nasal passages by reason of the interference which they produce with the freedom of the respiratory current through the side toward which they project.

The triangular cartilage of the septum may be torn from its bony attachments either posteriorly or inferiorly, or the extent of the diastasis may involve both lines of attachment. Such an injury results from blows upon the anterior portion of the nose, more especially in children. A lateral cartilage may be torn away from its attachment to the edge of the nasal bone, with or without injury to the septum. Deprived of its natural support, such a cartilage tends to fall inward, making the lower edge of the nasal bone to appear as a lateral prominence.

The fracture of the nasal bone may be a minor incident in a more extensive injury involving the bones of the face and orbits. If the nasal process of a superior maxillary bone is involved, rupture and obstruction of the lacrimal duct are possible complications. In one case which came under my observation, the entire bony framework of the face and of the orbit on the left side was crushed by a mass of iron chain which fell upon it, tearing away the left eye and cheek. Both nasal bones were fractured. In another case, by the kick of a horse the bones of the face were separated from the cranium by an open line of fracture through the superior maxillary, nasal, and ethmoid bones. Even in these cases of extensive and multiple injuries it is important that the condition of the nasal bones be appreciated and the best possible position for them secured, so that the ultimate deformity may be as slight as possible, for recovery from very extensive crushing injuries of the face is not infrequent.

By far the most frequent seat of fracture of the nasal bones proper is at some point along their lower half, where they are thinnest, least supported by other bones, and most exposed to violence (Fig. 218).

According to the location of the fracture and the direction of the injuring force, there may be—first, a deviation of the fragments to one side, with or without special depression; or second, a sinking in of the bridge of the nose with an uptilting of the tip; or third, a flattening and depression of the tip with broadening of the base. Depression of the bridge or tip necessarily involves fracture or displacement of

FIG. 218.—Fracture of the nasal bones (Hoffa).

the septum. Comminution of the fragments is frequent, and so also is laceration of the cutaneous or mucous covering, exposing the line of fracture.

Treatment.—The reposition in their normal position of displaced fragments of the septum and bony arch of the nose is to be accomplished by careful manipulation by the fingers applied externally, aided, if necessary, by the insertion of suitable levers and forceps into the nasal cavities, whereby depressed fragments may be lifted up and deflected parts straightened. Any lever intended to press up a nasal bone must be quite thin, not more than $\frac{1}{8}$ inch in thickness, on account of the narrow space between the bone and the septum. Such a lever, of suitable thickness and length, may usually be readily extemporized with a pocket-knife out of a slip of wood. A pocket-case director or even a hairpin may prove serviceable.

Not infrequently such impaction of the displaced fragment will exist as can be overcome only by the use of considerable force. When ordinary means fail to reduce such an impaction, it would be justifiable to drive a narrow chisel through the skin from without underneath the fragment and pry it up into place. It may be necessary to place the patient under the influence of a general anesthetic to secure tolerance of the necessary manipulations. No hesitation should be felt in resorting to such anesthesia whenever required to facilitate adequate examination and proper adjustment.

Whatever displacement or deflection of the septum exists may best be remedied by the use of forceps with flat parallel blades, by which the septum is seized and forcibly replaced. Recurrence of the deflec-

tion may be prevented by a tampon in the nasal passage toward which the displacement tends to occur, or by fixing the septum in place by pins thrust through it from above downward or from before backward, in such a manner as to control the movable lacerated part and hold it in the required position until healing has become well advanced.

This use of fixation-pins is preferable to the use of intranasal tampons, since the respiration is not obstructed, and opportunities of inspection and irrigation of the parts are freely afforded. The pins used may be the ordinary steel toilet-pins with glass heads. The point may be thrust through the anterior part of the septum, just within the nostril, and carried backward to be buried deeply in the portion beyond the line of fracture; or it may be introduced through the outer wall of the nose, and carried downward by the side of the replaced septum until it has become firmly engaged in the intermaxillary suture.

When both nasal bones are comminuted, and especially when the nasal processes of the superior maxillary bones are also fractured, the fragments may best be kept in place by the device, suggested by Mason, of passing a pin transversely through the nose under the fragments, entering it in the line of fracture in the nasal processes. A pin so placed gives reliable and constant posterior support to the fragments. Lateral compression, if needed, can be obtained by stretching a ribbon of rubber tissue $\frac{1}{2}$ inch wide over the bridge of the nose, either end of the ribbon being punctured and secured by an end of the pin. Should the line of fracture not be sufficiently symmetrical on the two sides of the nose to permit the passage of the pin in the desired line, the unbroken bone should be pierced with a drill at the desired level, so as to permit the pin to be carried through it. At the end of a week consolidation will be sufficiently advanced to insure the retention of the fragments in their proper position without the aid of the pin, so that it may then be withdrawn.

In the primary dressing of a compound comminuted fracture of the nasal bones, no fragment of bone should be removed unless it is entirely detached from the soft parts and lies loose in the wound, since any loss of substance in the framework of the nose entails noticeable deformity.

In occasional instances some emphysema of the eyelids and face results from air forced into the superficial tissues in efforts at blowing the nose. It calls for no treatment, for it will subside spontaneously within a few days.

Malar and Superior Maxillary Bones.—Fractures of the nasal process of the superior maxillary bone have been mentioned in connection with fractures of the nose. More or less of the alveolar process, especially in front, may be broken off by blows the brunt of which has fallen upon the mouth. The cheek-bones generally both share in the result of any violence severe enough to produce a fracture in either, although it is possible for the orbital or zygomatic process of a malar bone to be alone fractured by the direct blow of a narrow body. In the more common, broadly extended blows that are received upon the cheek, the malar bone together with the prominent malar process of the superior maxillary bone receives the chief impact; and if the force is a crushing one, according to the direction of the blow the

malar process is broken across and with the malar bone is displaced backward into the zygomatic fossa, or the malar is driven inward into the cavity of the antrum or upward into the floor of the orbit. Extensive laceration of the overlying soft parts and much comminution of bone often complicate such fractures. The flattening of the cheek which results when the cheek-bone has been driven backward or inward is a deformity that is at once recognized by both sight and touch; it declares plainly the nature of the injury. Further irregularities of bony outline may also possibly be felt by the finger applied to the margin of the orbit or to the outer and posterior surface of the bones accessible from the buccal cavity. Mobility and crepitus may also be elicited whenever the fragments are not immobilized by impaction. Injuries to the lachrimal canal or to the infra-orbital nerve, when present, will declare themselves by the special symptoms caused by interference with their functions. Protrusion of the eyeball may result from the encroachment upon the orbit of the displaced fragment or from hemorrhage into the cavity behind the ball. In cases of backward displacement into the zygomatic fossa, the movements of the lower jaw may be restricted.

The character of the **treatment** to be adopted will depend upon the extent and nature of the displacement. In cases in which the displacement is slight and the deformity of but little moment, if the fragment is loose, it may be restored to its place by pressure of a finger passed under it through the mouth; if it is too firmly fixed by impaction to be thus moved, the fracture may be disregarded and the case treated as one of simple contusion. If the disfigurement is considerable, and cannot be overcome by simple manipulation, an incision through the skin should be made, sufficient to permit a blunt hook to be passed under the most depressed border or process, by means of which it may be lifted up into place; or through a narrower puncture a gimlet or screw may be driven into the anterior surface of the depressed bone and used to lift it up; or the antrum may be opened from the mouth sufficiently to permit the introduction of a metallic instrument strong enough to force or pry up into position the depressed fragment. In open fractures the wounds of the overlying soft parts give ready access for such procedures to the fragments beneath. When the bones are comminuted, every fragment not wholly detached should be preserved with care, and the parts moulded back into as good shape as possible. Rapid repair is the rule in these injuries, and the ultimate disfigurement is often far less than could at first have been expected, even after extensive crushing injuries, provided actual loss of substance has been avoided.

Retention of the fragments in place after reposition ordinarily requires no special provision. Any tendency of a fragment to drop downward—a tendency more likely to be met with in fractures involving the alveolar process—can be controlled by using the lower jaw as a splint, the lower jaw being immobilized by the head and chin figure-of-8 bandage. The upper and lower dental arcades may be separated by a strip of gutta-percha placed on either side. These strips should be sufficiently thick to separate the jaws enough to permit of the introduction between the teeth of liquid food, a suitable space between the

strips being left for the purpose. The gutta-percha for such interdental splints is first softened by immersion in hot water, and, while still soft, is put in place so that it shall mould itself to the irregularities of the teeth and thus provide against displacement.

A very movable and depressed malar bone was supported and retained in place by Abbe by means of a drill passed through the solid part of the zygoma. The drill was withdrawn after ten days, and the bone healed without deformity.

The Lower Jaw.—The exposed position of the lower jaw often causes it to receive violence sufficient to fracture it. The anterior part of the body of the bone, between the mental foramen and the symphysis, is the site of the fracture in much the larger proportion of instances, but no part of the bone is free from the possibility of fracture.

FIG. 219.—Fractured lower jaw. Photograph of specimen showing most frequent location and direction of fracture. Internal and external surfaces.

Complete fracture at two or more points distant from each other is not infrequent. Partial fractures involving the alveolar border are very common from blows upon the teeth or in the extraction of teeth.

In complete fractures of the body of the bone the line of fracture is usually transverse to the long axis, and with but little, if any, antero-posterior obliquity, except in fractures in the posterior half of the body of the bone, in which region the anterior fragment is usually longer on its inner side, and the posterior fragment on its outer side.

The comminution caused by gunshot fractures produces multiple lines of fracture that are not susceptible either of classification or of systematic description.

The soft parts, both externally and also within the mouth, are frequently so lacerated as to render the fracture a compound one. Ordinarily there is but slight displacement of the fragments, and what there is may be readily corrected by manipulation. In occasional instances, as the direct result of the special violence which has caused the fracture, a more marked degree of displacement may exist, and the entanglement of a tooth or a bit of the alveolar process between the frag-

ments or the interlocking of projecting serrations may render replacement in apposition more difficult, and may require free exposure of the line of fracture by suitable incision, in order to detect and remedy the cause of entanglement. Fracture at the neck of the condyle leaves the condyloid fragment subject to the unopposed action of the external pterygoid muscle by which it is drawn upward and forward. In double fractures of the body of the bone the intermediate piece is drawn downward and backward by the unopposed action of the muscles of the neck attached to it.

Complete laceration of the inferior dental nerve is a comparatively rare complication, the more common location of fracture being in front of its point of escape from the dental canal at the mental foramen, and the displacement in other cases being rarely great enough to rupture the nerve. When the nerve is ruptured, there results anesthesia of the lower lip and chin on the affected side.

The **diagnosis** of fracture of the lower jaw rarely presents any difficulties. The history of direct violence sustained by the part and local impairment of function with swelling and tenderness invite examination. Often some irregularity of outline can be appreciated at once by both sight and touch, and by manipulation the mobility of the fragments and crepitus can be elicited, and the exact site of fracture demonstrated.

The **prognosis** is good. Failure of union is rare even in cases of comminution with some loss of substance, notwithstanding the frequent unavoidable movements between the fragments in swallowing and speaking. Nor are the rapidity and certainty of repair much prejudiced by the lacerations of the soft parts, which expose the fracture to contact with the copious secretions of the mouth, mingled with the secretions from the infected wounds.

Exfoliating splinters may cause abscesses, but necrosis, except of limited portions of the alveolar border, is rare. Deformity, beyond possibly a slight irregularity of the teeth not sufficient to interfere with mastication, is rare.

Treatment.—Replacement of the fragments in proper position in most cases is readily effected by slight pressure and manipulation. In the exceptional instances in which difficulty is met with, the cause for it must be sought for and removed. Loosened teeth at the point of fracture should be removed. Obstinate recurrence of displacement due to contraction of unopposed muscles calls for division of the muscles at fault. Such obstacles to ready and complete reduction and retention having been removed, retention of the fragments in position may usually be sufficiently secured by bandaging the lower jaw to the upper by a simple figure-of-8 chin-and-head bandage, applied over a chin-cup formed of canton flannel or towelling saturated with plaster-of-Paris cream. To form this cup a piece of canton flannel is saturated in thick plaster-of-Paris cream and folded into three folds; the folded piece for an adult should be from 6 to 8 inches long and from 3 to 4 inches broad. This is cut along the middle from either end for one-third of its length, the middle third being thus left uncut. From the center of either edge of this middle portion as much as may be required for the lower lip and for the throat is cut away. This uncut

portion is applied to the chin, which it will cover from the hyoid bone to the furrow below the lower lip. Then the two lateral tails are pressed upon the sides of the jaw, and the whole secured in place by the figure-of-8 bandage. When the plaster has hardened the cup should be removed and lined with a thin layer of cotton-wool or other soft material. It is then reapplied and kept in place by the bandage as before. Such a chin-cup is especially indicated to prevent displacement from lateral pressure of the bandage when the fracture is posterior to the mental foramen or when it is multiple. When the fracture is an open one with a skin-wound, suitable fenestration of the cup and bandages must be provided to facilitate its proper care, and the necessary absorbent dressings will be superadded to the fixation-appliances.

Careful inspection of the parts should be made as found to be necessary for the perfect support of the fragments and the comfort of the patient. Feeding with fluids can usually be satisfactorily accomplished through the spaces left by lost teeth or the natural irregularities of the dental arcades. Cleanliness of the mouth may be secured by the frequent use of antiseptic mouth-washes introduced through the same channels.

Repair takes place rapidly, so that by the third week the constant use of the retentive apparatus may be intermitted. It may be abandoned altogether by the end of the fourth week, but not until the lapse of two weeks more should the mastication of meat be attempted.

Should it be found impracticable to introduce liquid food between the closed jaws, or should the absence of teeth in either jaw be so extensive as to prevent the proper support of the lower jaw by the upper, interdental splints may be used, as already described in connection with fractures of the upper jaw. In the absence of facilities for making interdental splints, feeding may still be satisfactorily accomplished as long as necessary through a tube introduced into the pharynx through the nasal passages.

Whenever difficulty is found in maintaining the fragments in apposition by the means already described, as in oblique and multiple fractures or in compound fractures which require frequent disturbance of the retentive apparatus for dressings, the fragments may be wired together by stout silver wire passed through openings made by a drill through the whole thickness of the body of the bone from before backward, at a quarter-inch or more distance from the line of fracture on either side, the bone having first been pierced by a suitable drill. The wires may be removed after three weeks.

The tying together of the fragments by stout thread or silver wire passed around sound teeth on either side and near the line of fracture has often been resorted to, but it is a feeble and inefficient device in the cases which require special support; even firm teeth may thereby be speedily loosened.

Many forms of elaborate apparatus have been devised, combining vulcanized interdental splints and an external framework, and chin-plate with appropriate nuts and screws to regulate pressure, secure adjustment, and hold together the fragments of a broken lower jaw

until consolidation has been secured. They are especially indicated in fractures with much comminution, as in some gunshot fractures. The co-operation of a dental surgeon is essential for the construction of any such apparatus.

The mouth is thoroughly washed with an antiseptic solution; any very loose teeth are removed, and the teeth cleansed from tartar. An impression of the upper jaw is then taken in modelling composition, and of the lower or fractured jaw in modelling composition or plaster. No attempt is made to put the fragments in proper position.

Plaster casts are made, on which the lines of fracture are clearly indicated (Figs. 220, 221).

FIG. 220.—Plaster cast or model, there being a fracture at the symphysis, also in the region of the third molar, which is absent (Moriarty).

FIG. 221.—Model of same jaw after treatment. The left central tooth, which was loose, was extracted. Observe how perfectly the articulation has been restored (Moriarty).

With a fine saw the cast is cut on these lines, and the plaster cast is articulated with the cast of the upper jaw. Plaster is run around to hold the severed portions in position, and then both upper and lower casts are put upon an articulator.

The process of making an aluminum, gold, or vulcanite splint is familiar to every dentist, being similar to that of making an ordinary plate.

The advantages of the aluminum, gold, or simple vulcanite splint

FIG. 222.—Aluminum or gold splint, which is cemented on to the teeth.

are that they are not noticeable, and that the patient can use the mouth, being able to open and close it, and can masticate with comfort.

The whole course of treatment of fractures of the lower jaw has been systematized by dental surgeons, and every conceivable variety of fracture has been treated by methods which are fully described in the journals devoted to that department of surgery.

FIG. 223.—Vulcanite splint with boxes vulcanized on each side. If the jaw is fractured in the region of the molars, considerable pressure is required to get the parts in position; therefore it is best to vulcanize on to the sides of the vulcanite splint boxes into which wire arms can be inserted.

The Hyoid Bone.—Notwithstanding the hyoid bone, by reason of its mobility and its retired position behind the projecting lower jaw, can rarely be exposed to fracturing violence, yet the immunity is not absolute. Blows upon the neck, or falls in which the front of the neck strikes upon the projecting edge of an object, or circular compression, as of the fingers in throttling or of the noose in hanging, have been the usual causes of the accident. Muscular action alone, in sudden and violent extension of the neck, is claimed to have been the cause in some instances. In the recorded cases the usual point of fracture has been at or near the juncture of the great cornu with the body of the bone. In a considerable proportion of the cases (6 out of 27, Gurlt) there was associated with it fracture of the cartilages of the larynx.

The **symptoms,** in addition to the local soreness, tumefaction, and ecchymosis, arise from the pain which is caused by acts involving contraction of the hyoid muscles. Swallowing is difficult and painful—for a time often impossible. Movements of the lower jaw and of the tongue awaken pain. The fractured cornu, displaced inward, has in some cases been felt by palpation with a finger in the pharynx. Crepitus cannot usually be elicited. When the larynx is also injured, the special signs of that injury are superadded, such as dyspnea, bloody expectoration, and, in severe cases, emphysema.

The **prognosis** depends largely upon the character of the associated injuries, which are often fatal. The fracture itself is usually susceptible of repair by bony union, but cases of such considerable displacement as to cause non-union have been recorded. Necrosis of the fragment has occurred.

The **treatment,** after any manifest displacement has been corrected by finger-pressure from within the pharynx, is necessarily restricted simply to measures to immobilize the neck, to combat the local inflammatory reaction, and to relieve the complications arising from associated injuries. The dysphagia, as long as it is severe, should be met by rectal feeding or by the use of an esophageal tube; dyspnea from edema of the glottis may call for intubation or tracheotomy. Immobilization of the neck may be secured by a broad posterior collar of plastic material, as canton flannel saturated with plaster of Paris, or sole-leather softened by hot water, the collar being fastened to the head and shoulders by appropriate bandaging.

The Sternum.—The sternum, by the sponginess and elasticity of its own structure and the elastic support which is given it by the

costal cartilages, is so protected from the effects of violence that it rarely becomes fractured. When fracture of the sternum does occur as the result of great crushing violence, it is not infrequently associated with such other severe lesions—as fractures of the spine, ribs, or skull, and laceration of the thoracic viscera—as to render of little importance the sternal injury. While the more frequent cause of fracture has been a direct blow or crushing force received by the bone, in a considerable proportion of the recorded cases the fracture has been caused by forcible and extreme bending of the trunk, either backward or forward. In a number of instances it has been caused by the violent muscular struggles of difficult parturition. In a case under my own care it was caused in a football scrimmage.

The part of the bone most frequently fractured has been that portion of the body lying between the manubrium and the point of articulation of the fourth costal cartilages. Diastasis at the junction of the manubrium and gladiolus presents no practical differences from a fracture, and does not require separate consideration.

In the great majority of instances the fracture has been transverse in its general direction, though cases of longitudinal fracture have been observed. The amount of displacement attending the fracture will depend upon the nature of the violence which has caused it; usually it is not great. Some projection forward of the upper edge of the lower fragment is usual, recognizable by sight and touch. Very marked depression of the upper fragment has been noted in some cases.

In addition to the usual signs of fracture there may be added symptoms of internal injury, varying according to the extent of internal laceration present, including dyspnea, cough with bloody expectoration, emphysema, and the signs of hemothorax. Infection may determine, later, widespread mediastinal suppuration. The prognosis is favorable, except in the presence of serious internal injuries. The fragments unite promptly by osseous or fibrous union, even when the displacement is marked and is not overcome.

In the **treatment** the patient should first be placed in the position in which he finds that he can breathe with the greatest comfort. This will usually be in a half-sitting position with a firm pillow between the shoulders. This position will at the same time tend to overcome the displacement. The displacement itself does not call for persistent and irksome attempts to overcome it, unless it is so great as to be the cause of embarrassment to the heart or lungs. In such a contingency any operative measure required to elevate the fragments would be justifiable. Otherwise the surgeon should content himself with what he can secure by position and moderate manipulation and pressure. The thoracic movements should be restricted by encircling the thorax with a broad band of adhesive plaster. Opium may be given for the double purpose of relieving pain and diminishing the frequency of the respirations. The complications of intrathoracic hemorrhage and of mediastinal suppuration, the first as an immediate and the second as a later occurrence, should be watched for, and such operative measures taken as are needed to expose the bleeding point or drain the pus-focus.

Ribs and Costal Cartilages.—Fracture of the ribs is a com-

paratively common accident. In my own experience it has occurred about one-half as frequently as have fractures of the femur, 39 patients suffering from fractured ribs and 72 from fracture of the femur having been admitted into the Methodist Episcopal Hospital, Brooklyn, during the period 1888 to 1895. The elasticity of the thoracic framework renders children less liable to this accident than adults, but it is occasionally observed even in quite young children; thus, among the cases above enumerated there was one child of three years who had six ribs broken by the kick of a horse, and another of six years who had three ribs broken, having been run over by a wagon. A similar cause produced fracture of two ribs in a boy of thirteen.

Violence sufficient to cause rib-fracture may act either by staving in the rib at the point of contact, or by so compressing the chest as to bend the rib outward until it gives way at some point along its continuity. The former is the usual mechanism. Out of 25 cases in which I have preserved a record of the nature of the violence done, 9 resulted from falls from a height, 7 were sustained in railroad accidents; in 4 instances the patient had been run over by a wagon; in 2 a crush beneath a falling body had occurred; in 2 the patient had been kicked or knocked down by a horse; and in 1 he had been crushed between the rollers of machinery.

Fracture of a rib has been alleged to have been caused by simple violent muscular action, as in parturition, and even in sneezing. It is reasonable to assume that a pathological fragility of the bone must have pre-existed to contribute to the production of a fracture from such a cause. While fracture may affect any part of a rib, any rib, and any number of ribs, the more sheltered upper two ribs and the more movable lower ribs are less frequently broken than the central group. Fracture by direct violence occurs with great frequency in front of the axillary line; fracture by indirect violence posterior to it, near to the angle; fracture of a costal cartilage has been noted more frequently near the costochondral junction.

Fracture at more than one point in the same rib occasionally occurs, and fractures of ribs on both sides are not rare. Thus, among the cases mentioned was one of a man, sixty-five years of age, who, after falling from a height, was found to have sustained double fractures of all the true ribs on the left side and fracture of four ribs on the right side.

The amount of displacement in most cases is insignificant, owing to the support which the adjacent unbroken ribs give to the broken one; but when several ribs are broken, so that the side sinks in, overriding and marked angular deformity may occur. Incomplete fracture and fracture without complete laceration of the periosteum the writer believes to be not very rare, in view of the clinical symptoms occasionally observed, but he has not been able to verify this opinion by autopsy.

Coincident injuries of thoracic or abdominal viscera, or of other portions of the body, frequently complicate fractures of the ribs, being the natural result of the kind of violence to which rib-fracture is most frequently due. These complicating injuries are important elements in both prognosis and treatment. Out of the 39 cases already referred to, 14 died. Two of these deaths were apparently due to profuse intrapleural bleeding from lacerated intercostal arteries; 3 were due to uremia from aggravation of pre-existing chronic nephritis; 1 was due to coincident fracture of the base of the skull and cerebral laceration; in all the remaining 8 cases there were ruptures of the abdominal viscera, usually of the liver, frequently associated with multiple contusions and fractures in other parts of the body. Laceration of the pleura is the necessary consequence of any notable displacement of the fractured rib-ends. The effect of this is, as a rule, to produce only a circumscribed adhesive pleuritis, but in occasional instances a diffuse suppurative pleuritis follows. It is but rarely that any considerable bleeding results from laceration of an intercostal artery; in exceptional instances, however, serious, even fatal, hemorrhage into the pleural cavity has been due to this source. More frequently a hemothorax is due to laceration of the lung-tissue. More or less laceration of a lung is a common result of a crush of the thorax; this may vary in degree from a limited contusion of the lung-tissue, with a variable degree of interstitial ecchymosis, to extensive tears that declare themselves at once by hemoptysis, of hemo- and pneumothorax, and emphysema, while bronchitis, pneumonia, or gangrene of the lung are later possible sequelæ. Wounds of the heart and great vessels have been reco-

The **symptoms** of fracture of a rib consist of sharp, circumscribed pain at the injured point, which is aggravated by the movements of respiration and by direct pressure. Moreover, pressure so applied as to increase the arch of the rib, as by compression made upon the sternum, will elicit pain at the injured point. Crepitus, unnatural mobility, and deformity may be observed in varying degree. These signs will be most easy to elicit when the injury is seated in the more superficial portions of the ribs, or when several ribs are broken. The symptoms and results of complicating laceration of the lung have been already briefly stated. In this connection it should be noted that the absence of the spitting of blood does not absolutely contraindicate the presence of lung-injury, while it also may occur in the absence of laceration of the lung-tissue.

The **course** of healing, in cases unaccompanied by serious visceral injury, is usually quite uneventful. The movements of respiration provoke the formation of an abundant ensheathing callus, and rapid bony repair is the rule. When several ribs have been broken, it may happen that the callus is abundant enough to determine the formation of lateral bony bridges, welding them all together. In the complicated cases, the course will be modified by the nature of the other injuries, in the presence of which the rib-injury becomes of but little moment. The spitting of blood, provoked by laceration of the lung, in the event of the injury not being severe enough to prove speedily fatal, generally ceases, in great measure, in the course of forty-eight hours, giving way to rusty sputa. Emphysema is a comparatively rare complication, and when it does occur, even though the extent of diffusion may be wide, it may be relied on, as a rule, to subside speedily and spontaneously. In the event of serious embarrassment from its extent and persistence, free incision, sufficient to ensure the ready external escape of the air pumped out from the lungs, will cut it short. Air within the pleural cavity, entering through a laceration of the lung, becomes a source of danger only when it has accumulated under pressure until it begins to compress the sound lung also. The establishment of an external vent suffices to relieve the special danger.

Bloody effusion into the pleural cavity becomes a complication requiring special attention in the rare instances in which its amount is so great as to compromise life by inducing acute anemia, and by attendant pressure-dyspnea. An effusion whose amount is not sufficient of itself to produce threatening symptoms may, by infection, give rise to a later empyema, with its special symptoms and indications for treatment. Copious intrapleural bleeding comes in most instances from lung-lacerations, only rarely from lacerated intercostal or mammary arteries. Cases of lesion of the heart or great vessels, quickly inducing death, have been recorded. The usual signs of progressive acute anemia, with urgent dyspnea, and the physical signs of fluid in the pleural cavity, supervening upon the reception of a blow upon the thorax, are sufficient to indicate the nature of the complication. The diagnosis may be corroborated by the use of an aspirator needle and syringe. While serious hemothorax is a more frequent occurrence after compound fractures and penetrating wounds of the chest, with or without fracture, yet it is an occasional complication of simple fracture,

and cannot be ignored in connection therewith. The spontaneous recoveries from extreme hemothorax, which are from time to time reported in surgical literature, ought not to be accepted as warranting any departure, in dealing with intrathoracic bleeding, from the principles of hemostasis established for other parts of the body—viz., to expose the bleeding vessel and to occlude it by ligature, compression, or cauterization, as the conditions of the particular case may indicate. The development of the symptoms of serious intrathoracic bleeding after rib-fracture will justify the surgeon in converting the simple into an open fracture by incision, and the raising of such a flap of the chest-wall, by double section of one or more ribs, as will secure the exposure of the bleeding point and render possible the necessary procedures for its closure.

The **treatment** of the fracture itself is simple. Any displacement that may not be spontaneously reduced may be corrected by suitable pressure. In the event of persistent depression which causes pain or irritation, the depressed fragments may be drawn outward to their proper level by a hook introduced underneath them through a puncture in the skin. The freedom of the movements of the chest-wall should then be restricted as much as possible by encircling the thorax with a broad strip of adhesive plaster 6 inches in width. This should be applied during forced expiration. Its center should, as a rule, pass over the site of fracture, but its lower border should not come lower than the ensiform appendix, lest it interfere with the freedom of abdominal breathing. The frequency of the respiratory movements may be lessened and pain may be controlled by full doses of opium during the first few days after the accident. By the end of the fourth week the special bandage may be dispensed with.

The Clavicle.—By reason of its length, its slenderness, and its function as the medium through which the root of the upper extremity is articulated with the trunk, the clavicle is often the subject of fracturing violence, particularly in young children, although no age is exempt.

The most common cause of the fracture is a fall upon the hand or elbow, or upon the projecting tuberosities of the humerus at the shoulder. The force in such cases is transmitted through the glenoid cavity of the scapula and the coracoclavicular ligaments, and finally culminates as a twisting strain upon that portion of the bone which lies internal to the attachment of the coracoclavicular ligament and external to that of the costoclavicular ligament. As a matter of fact, by far the great majority of the fractures of the clavicle have their seat in the outer half of the middle third of the bone. When the force is received from behind, as by falls upon the outer and back part of the shoulder, the acromion, violently driven forward, carries with it the acromial end of the clavicle. When the free forward movement of this portion of the bone is arrested by its muscular and ligamentous attachment to the trunk, a crossbreaking strain is created, and more or less of the acromial end of the clavicle may be torn off. A fall upon the top of the shoulder, or a blow received at that point from a falling body, may also by direct force fracture the acromial end of the clavicle. Fracture of the outer end of the clavicle is much less frequent than

fracture of the middle third of the bone, being in the proportion, according to Gordon, of about 1 : 4. Fractures near the sternal end of the bone are of very rare occurrence. To cause indirect fracture at

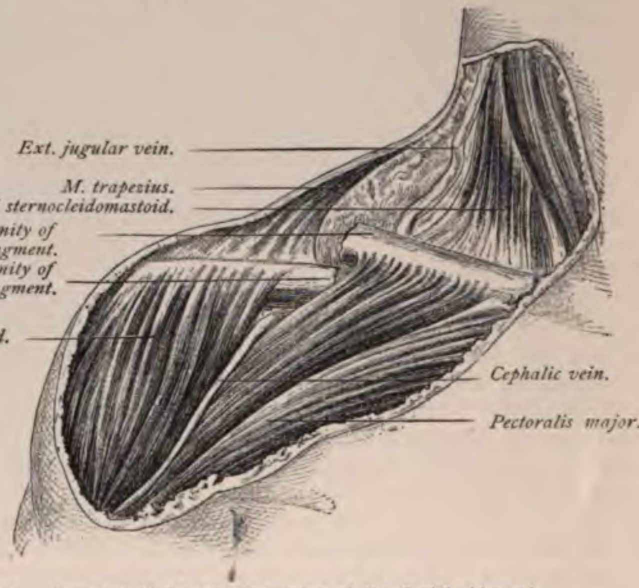

FIG. 224.—Fracture of the middle portion of the clavicle (Anger).

this point, it must be presupposed that a crushing force has been sustained upon the outside of the shoulder, which is transmitted directly in the longitudinal axis of the bone to its fixed sternal end. More

FIG. 225.—Fracture of sternal end of clavicle; inferior and anterior aspects.

frequently, in this contingency, the ligaments give way, and a dislocation of the sternal end of the clavicle results. In rare instances the bony tissue is disrupted, and a fracture, with some impaction and comminu-

tion, is produced. Fig. 225 represents a specimen taken from a patient of the author. The man fell from a rapidly moving railroad car and struck upon his right shoulder, crushing the head of the humerus and the sternal end of the clavicle upon that side, as shown in the illustration.

The clavicle may be fractured at any part of its course by direct blows, but fracture from such cause is not common. For this reason, comminuted and compound fractures are rarely met with, and leaving gunshot fractures out of consideration, injuries to the blood-vessels and nerves at the root of the neck are exceedingly rare as complications of fracture of the clavicle. On the other hand, the special mechanism of the indirect fracture often causes the break to be incomplete, especially when the spongy and elastic clavicle of a child is involved. Many cases have been recorded in which the clavicle has been broken by violent muscular contractions alone, as in an attempt to lift a heavy weight, or to make a strenuous effort with the attached upper extremity, as in an instance under the observation of the writer, in which a young woman, who was bathing in the surf at the seashore, was violently lifted and swept from her feet by an incoming roller. While striving to maintain her place by clinging to a fixed rope provided for the purpose, she felt something give way in her neck, and afterward, upon examination, was found to have sustained a typical fracture of the middle third of the clavicle.

In the common break along the middle third of the bone in adults the line of fracture is generally oblique, running inward and downward or backward; in children, transverse fracture is not uncommon. Variations from these more common lines are not infrequent.

A quite uniform displacement so often follows this fracture as to be characteristic of it. The end of the outer fragment slips behind and below the inner fragment, so that the end of the inner fragment is tilted upward and forward, forming a notable projection at the base of the front of the neck. This upward tilting may be increased by the contractions of the sternocleidomastoid muscle.

The primary cause of this displacement is the continued action of the forces which break the bone. These forces, as has been seen, may be arrested when the bone is only partially fractured; a greater force results in a complete fracture without much displacement; a yet greater force tears the movable broken end to a more or less extent from its fibrous and muscular attachments, and thrusts it backward and inward behind its stationary fellow. The contraction of the muscles which pass from the thorax to the clavicle, scapula, and humerus tends to maintain the displacement. The scapula glides forward and somewhat downward upon the convexity of the thorax, controlling the outer fragment of the clavicle, which is bound to it. Conversely, by drawing the scapula backward the attached clavicle fragment is pulled with it, and usually may thus readily be made to fall into proper relation with the sternal fragment.

Fractures of the clavicle external to the innermost attachment of the coracoclavicular ligament often display a marked displacement of the scapular fragment forward and inward, even to the extent of forming a right angle with the sternal fragment, as shown in the accompanying illustration (Fig. 226).

FIG. 226.—Section showing the relation of the fragments after fracture of the acromial end of the clavicle, healed in displacement (R. W. Smith).

Diagnosis.—The symptoms produced by fracture of the clavicle vary in their severity according to the extent of the displacement and

the laceration of the soft parts. Local tenderness upon pressure, more or less ecchymosis, and some restriction of the free use of the attached arm, owing to pain in the neck caused by muscular efforts, may be all that at first attend the less severe injuries, in which the break is incomplete or not attended with displacement. Within a few days the development at the injured point of an easily recognizable mass of callus will suffice to confirm the diagnosis. In the more common fracture with displacement, inspection of the neck shows at a glance the resulting deformity caused by the projection of the inner fragments, and the position of the fragments and their unnatural mobility can be readily determined by the touch. A posture characteristic of the accident is involuntarily assumed by the patient as he inclines his head and neck to the injured side, and supports the elbow and forearm by the hand from the sound side. When the displacement is reduced, crepitus may be elicited. The amount of limitation of function displayed by different individuals with practically the same amount of local injury varies, depending upon the sensitiveness to pain which the individual may possess. The movements of the upper extremity can be made as freely after the accident as before, and whatever limitation seems to be present is a voluntary one on the part of the patient, to escape pain. Upon cursory inspection, fractures near either end of the bone may be mistaken for dislocations, but care in examination will reveal the true nature of the accident.

Prognosis.—Rapid repair with bony union usually follows this injury, even in the presence of marked displacement. Firm union by the end of the fourth week is the rule in adults. Cases of non-union have been reported, but in these cases the usefulness of the arm has been very little impaired. So great are the practical difficulties in overcoming the tendency to displacement which marks the usual fracture, that perfect success in avoiding deformity is rarely obtained (see Fig. 227).

FIG. 227.—Healed fracture of the clavicle, united in extreme deformity (Gurlt).

Treatment.—In the cases of fracture without displacement, notably in the incomplete fractures of children, nothing more is required than a simple sling to support the forearm and a broad bandage binding the arm to the thorax, such as may be worn with comfort, to prevent any such free use of the arm as might aggravate the local injury. If the arm is not inserted into the sleeve of the dress or coat, but, supported in its sling, is fastened up within the body of the buttoned or pinned garment, every indication will be satisfied.

In the frequently occurring cases with displacement, the ingenuity of the surgeon is often taxed to its utmost to retain the fragments in their proper position sufficiently to secure union without deformity; in a very large proportion of cases, despite every effort, notable deformity persists. This is due not to the difficulties in bringing the fragments into proper relative position, but to the fact that any efficient retentive bandage or apparatus is so irksome that it soon becomes intolerable. A multitude of different forms of apparatus have been devised, and their

description burdens the pages of surgical treatises; the fact remains that those which are efficient are intolerable, and those which are tolerable are inefficient, and that, as a rule, the good results which are claimed from their use could have been equally well secured by simpler means, or were due to the specially favorable nature of the particular cases. The prime indication is to keep the scapula pushed well backward around the convexity of the thorax toward the spine, and to press its posterior border closely against the ribs. The acromion is thus carried outward, and with it goes the outer fragment of the broken clavicle. The value of the dorsal decubitus, unaided by apparatus of any kind, to secure this desired fixation of the scapula is well established. To secure its best results the mattress must be firm and even. A thin pillow may be used for the head only, so as to relax the sternocleido-mastoid muscles. The elbow should be kept close to the side, while the forearm may be brought over upon the front of the body and supported there by a suitable sling. After about two weeks, the processes of repair will be so far advanced as to enable this position to be dispensed with, without much danger of any later displacement occurring. A supporting sling and a restraining bandage should be worn for another two weeks, or until firm consolidation has taken place. It is rare, however, that the mere question of symmetrical union will be deemed of enough importance by a patient to induce him to undergo the irksome confinement of the unremitted dorsal decubitus for the required length of time.

Of the various devices that have been suggested for controlling the scapula, the one that has given me the most satisfaction is that of a pair of stuffed collars made of a firm roll of flannel covered with muslin, one encircling snugly each arm at the shoulder. These are connected by a strap of bandage across the back, by tightening up which the scapulæ may be pulled backward toward the spine with force and held there securely.

A moderate-sized pad is next fitted in the axilla of the injured side, not with the idea of any use as a fulcrum over which to exercise leverage with the arm to pry the shoulder out—an impracticable notion—but simply to afford a more comfortable support for the arm as long as it is to be confined to the side. This pad should be held in place by a sufficient number of turns of a roller bandage encircling the thorax. The hand is now placed on the front of the chest, the forearm being flexed at an acute angle with the arm, which latter remains at the side, falling perpendicularly from the shoulder. Any attempt to advance the elbow in front of the chest or to carry it posteriorly tends to shift the acromion forward, and is therefore to be avoided. The dressing is now completed by circular turns of roller bandage, which, beginning at the level of the elbow, bind arm and forearm securely to the thorax. When the forearm has become fully covered in by the bandage, the head of the roller, as it comes across the back, is brought around under the elbow, and thence directly upward over the shoulder of the same side, and down again behind to the elbow. From three to four of these perpendicular passes should be made. By them the horizontal turns are reinforced and fixed in position. Abundant pins are finally

introduced at points where the turns of bandage cross each other, and the dressing is completed.

Frequent inspection and readjustment of apparatus is especially necessary in the treatment of fracture of the clavicle. By the fourth week the consolidation is usually so firm that special apparatus may be discontinued and the arm entrusted to a simple sling, which, after another fortnight, may be cast aside.

Exposure of the seat of fracture by incision, replacement of the fragments in proper position, and fastening them together by sutures or dowel pin, may become necessary in those rare cases in which either other means have failed to overcome the tendency to displacement, or it is especially important to avoid deformity, or the symptoms of pressure upon blood-vessels or nerves exist, or penetration of the skin threatens or has already taken place.

The Scapula.—Most fractures of the scapula are due to direct violence, but the mobility and the muscular paddings of the bone, and

FIG. 228.—Fracture of the body of the scapula (Warren Museum).

the elasticity of the thorax, against which it rests, cause its fracture from any cause to be a rare occurrence. The processes which enter into the mechanism of the shoulder may be fractured indirectly, also, by violence transmitted through the humerus, the chipping away of more or less of the rim of the glenoid cavity being the most frequent of the indirect injuries; and when this occurs, it is usually associated with dislocation of the head of the humerus.

Cases have been reported in which the coracoid process was torn off by muscular contraction alone. The acromion process, by its prominence, is especially exposed to vulnerating influences, and its fracture is of nearly equal frequency with that of the body of the bone. As in the case of all fractures from direct violence, such injuries of the scapula are little susceptible of systematic classification; any portion

of the bone may be fractured, and widely varying degrees of comminution and of injury to the overlying soft parts will exist.

Displacement of the fragments to a noticeable extent is not usual in the injuries of the body of the bone, and, when present, is the immediate result of the violence sustained rather than of muscular contraction; hence it is not apt to recur after replacement by suitable manipulation. An exception to this statement is to be noted when a small portion of the posterior edge or of the superior angle is broken off, the unopposed action of the rhomboids or of the levator anguli scapulæ being sufficient to cause considerable displacement of the

FIG. 229.—Fractures through the rim of the glenoid cavity (Gurlt).

fragments to which they may be attached. When the acromion is broken off, the deltoid tends to draw the fragment downward and to flatten the shoulder; after coracoid fracture, displacement may be limited by the still intact coracoclavicular ligaments. Fractures involving the glenoid cavity, including fractures of the neck of the scapula by which a fragment, including the whole articulating cavity, is broken off, exhibit the most marked displacement, since the scapular fragment follows the head of the humerus.

The **diagnosis** will be based on the presence of the usual signs of fracture, which ordinarily are readily apparent upon examination. Difficulty may attend the recognition of the injuries of the glenoid rim and of the neck of the scapula, on account of the resemblance which its conditions present to that of dislocation of the humerus, which may also be present as a complication. When a small portion of the glenoid rim is chipped off in connection with a dislocation, it may escape recognition altogether, unless in the manipulations for reduction crepitus should be noticed. The absence of signs of a more extensive injury of the scapula or of the humerus would indicate the particular lesion that had occurred. When the fragment that has been split off involves a considerable portion of the glenoid cavity, as in Fig. 230, the head of the humerus and the fragment will slip away from the scapula into the axilla, the condition simulating a dislocation. The displacement is easily remedied by properly applied pressure, but it at once recurs when support is withdrawn; crepitus may be elicited during the manipulations. The same symptoms will attend a fracture of the neck of the scapula, which passes posterior to the base of the coracoid process, if the coracoclavicular ligaments have been torn, but they may be distinguished by the fact that in the latter condition the coracoid process follows the movements of the humerus, while in the former condition it moves with the scapula. The contour of the shoulder is markedly flattened in both conditions, and by this fact they are differentiated from fractures of the neck of the humerus, which are not attended with loss of the normal rotundity of the part.

Rapid bony repair is the rule in fractures of the scapula, except when the acromion or the coracoid process is the part broken off, in which cases ligamentous union is common.

The **treatment** consists in the adjustment of the fragments by manipulation, followed by fixation of the scapula by an arm-and-body bandage. In general, the bandage that has already been described in connection with fractures of the clavicle will be most suitable for fractures of the scapula also, the shoulder-collars being omitted. The bandage of Velpeau will also answer well, except in cases in which the posterior border is torn off.

The Humerus.—Fractures of the humerus naturally group themselves, according to the location and relations of the part of the bone injured, into fractures at the shoulder, fractures of the arm proper, and fractures at the elbow. Notable differences characterize injuries in these three regions as to the methods of their production, their course, their consequences, and their treatment.

FIG. 230.—Comminuted and impacted fracture of the head of the humerus; head driven downward and inward (Malgaigne).

The shoulder-injuries comprise all the fractures involving the part of the bone above the insertion of the axillary muscles. The head, the anatomical neck, the two tuberosities, and the surgical neck fall within this limit, and in youth the irregular epiphyseal line is also included. Fractures of this portion of the humerus result from falls upon the shoulder or impact of falling bodies against it, and, according to the nature and direction of the crush, the extent of injury may vary from a longitudinal fissure of limited extent, which during life may be indistinguishable from a mere contusion, to a comminution of the whole upper part of the bone by multiple radiating lines of fracture, with impaction of fragments into each other or with marked displacement. Figs. 230 and 231 show examples of the more severe forms of fractures at the shoulder.

Fracture through the surgical neck is by far the most frequent break in this region, and is, with reference to other fractures of the humerus, a relatively common accident. Thus, of 203 fractures of the humerus examined by Hamilton, 44 were at or near the surgical neck, 6 were supposed to be epiphyseal separations, only 1 was thought to be a fracture at or near the anatomical neck, with impaction and splitting of the tubercles, and 1 was a fracture of the greater tubercle alone. These figures, which in general are in accord with the observations of others, serve to show both the frequency of breaks through the surgical neck and the rarity of recognizable fractures through that part of the bone above the epiphyseal line. There is, however, a much greater proportion of cases in which the head of the humerus has been severely contused, and in which although both deformity and crepitus are absent, so that a positive diagnosis of fracture cannot be made, yet the persistence of pain and muscular rigidity and the location and extent of the ecchymosis are such as to warrant the diagnosis of incomplete fracture, or of fissure, or of fracture in which the continuity of the bone is maintained by untorn periosteum, with or without slight impaction. The repair of these fractures is so complete that their traces are too slight to arrest attention when, in after years, the subjects come to the dissecting table, and thus they are absent from museum shelves and do not enter into statistics. Fig. 232 shows a case in point of fracture limited to the tuberosities, with a slight degree of impaction, which might have

escaped recognition during life had not the fracture been associated with a compound dislocation of the head of the humerus. The case is recorded by Bardenheuer.[1]

FIG. 231.—Comminuted fracture of the head of the humerus; primary line of fracture through anatomical neck, secondary splitting away of the great tuberosity (photograph from specimen in Museum of the M. E. Hospital, Brooklyn).

In **fractures of the head of the humerus** the line of separation, as a rule, runs irregularly, possibly through part of its course within the capsule, following the anatomical neck, and then diverging into the region of the tuberosities (see Fig. 231). More or less splintering of the expanded upper end of the shaft is common. The liability to impaction has already been alluded to. In the greater number of cases the fragments are not entirely separated, but, in addition to some degree of impaction, are more or less closely held together by untorn periosteum and the fibrous tissue of the capsule and tendon-sheath that invests the part.

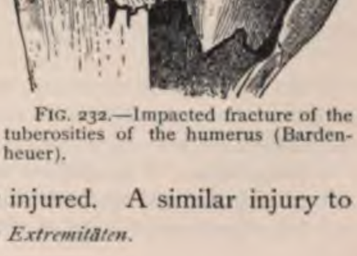

FIG. 232.—Impacted fracture of the tuberosities of the humerus (Bardenheuer).

A portion of either tuberosity is occasionally torn off as a part of the injury accompanying a dislocation, the greater tuberosity being the part most frequently injured. A similar injury to

[1] *Die Krankheiten der oberen Extremitäten.*

a tuberosity has resulted from violent muscular effort alone. In fractures below the tuberosities through the surgical neck, the displacement is also often incomplete, owing to the frequency of a transverse or dentated line of fracture and the thickness of the fibrous tissue which invests the bone here.

When complete displacement does occur, the upper end of the lower fragment is commonly drawn forward and upward toward the coracoid process, where it forms a prominence that can both be felt and seen. A backward displacement may result from the special direction of the force to which the fracture may have been due. At any age up to the twentieth year the line of fracture may run through the epiphyseal cartilage. When complete disjunction of the epiphysis is produced, the upper end of the diaphysis is usually displaced forward, making a noticeable projection in front of the shoulder. The upper surface of this projecting bone is smoother and more rounded than the irregular or dentated end of the lower fragment left after the common fracture of the surgical neck. The condition may be mistaken for a forward dislocation of the head of the humerus, until more full examination shows that the rotundity of the shoulder has not been lost, and that the head of the humerus is still present in the glenoid cavity. The epiphyseal fragment may be rotated by the muscles which are inserted into its tuberosities, until its under concave surface looks forward and outward. Efforts to bring the epiphysis and diaphysis into their normal relations are liable to be ineffectual, owing to the mobility

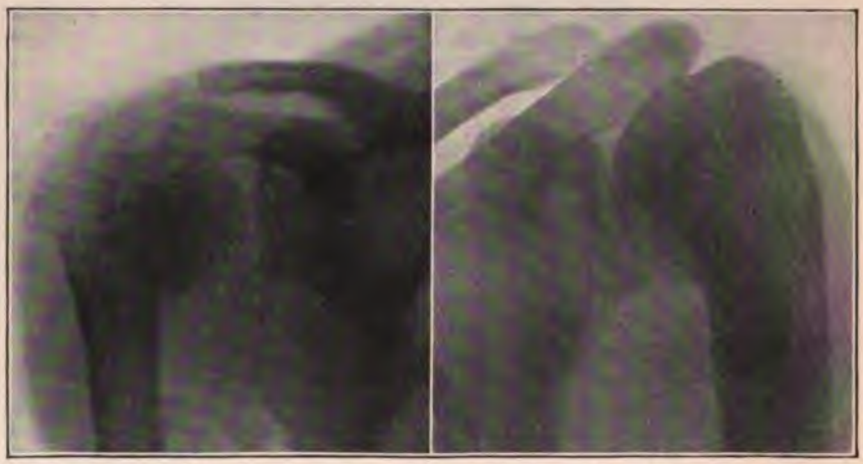

FIG. 233. FIG. 234.

FIGS. 233, 234.—Fracture of the head of the humerus through epiphyseal line (Wharton). Fig. 233 shows the relation of the fragments immediately after the accident; Fig. 234 shows the condition one year later: consolidation with deformity (skiagraphs by Goodspeed).

of the epiphyseal fragment and the tendency of the projecting anterior edge of the upper end of the diaphysis to become entangled in the concavity of the upper fragment (Figs. 233, 234).

Diagnosis.—It is evident from the statements in the preceding paragraphs that in many cases the exact differential diagnosis of fractures of the upper extremity of the humerus is difficult and in some cases

impossible, a probable or approximate diagnosis being the most to which a prudent surgeon should commit himself. Fractures without notable displacement and fractures with impaction give symptoms that are not to be positively distinguished from those of contusion without fracture, as long as the surgeon refrains from such forcible manipulations as, by breaking up impaction and rupturing previously untorn periosteal and fibrous bands, might succeed in eliciting crepitus and producing recognizable displacement. On the other hand, the injunction cannot be made too emphatic that such forcible manipulations for the purpose of reaching a positive diagnosis should never be resorted to. The swelling of the overlying soft parts may be such as to obscure signs that might otherwise be distinguishable. In the examination of all shoulder-injuries, all clothing should be removed from the upper part of the body, so as to permit a careful inspection of the injured part and its comparison with the sound side by sight, touch, and measurements. Dislocation at the scapulohumeral articulation is first to be excluded by determining the presence of the head of the humerus in the glenoid cavity. In rare instances there occur simultaneous dislocation and fracture, in which cases examination reveals not only the absence of the head of the humerus from the glenoid cavity and its presence in an abnormal situation, but also the special signs of fracture. Swelling, tenderness on pressure, pain on motion, muscular spasm, and ecchymosis are common to all injuries; but when they occur at the shoulder after an injury to the head of the humerus, in the absence of dislocation, if they are persistent and deep-seated, and especially if the ecchymosis is extensive and is effused beneath the deeper planes of tissue, a probable diagnosis of incomplete fracture, or of fracture with impaction, is warrantable. If by careful manipulation, combining traction with rotation, crepitus is elicited, the diagnosis is made positive. When there is no impaction and the fracture is complete, the deformity from displacement, the false point of motion, and the crepitus may combine to declare unmistakably the exact nature of the injury.

The *prognosis* in the case of these fractures of the humerus at the shoulder, so far as union of the fracture is concerned, is almost invariably good. In the cases of impaction, consolidation of the fragments in their new relations occurs quickly; in fracture with imperfectly reduced displacement, abundant callus forms a firm bond of union; but in both classes the irregular position of the fragments and the possible formation of osteophytic masses may limit the motions of the shoulder-joint, and even in the absence of such bony obstacles to free motion, intra-articular fibrous adhesion and thickening and contracture of the peri-articular tissues may greatly limit, and even totally destroy, the function of the joint. Atrophy of the shoulder-muscles is the rule, and in some cases it is very notable. In the more favorable cases, the stiffness of the joint and the muscular atrophy are gradually overcome, and complete disappearance of all disability results.

Treatment.—Impacted fractures, incomplete fractures, and fractures with little displacement require simply that the parts should be immobilized and supported by a broad bandage confining the injured arm to the side of the chest, while the hand and wrist are supported in a sling. Should the primary swelling and pain attending the injury be marked,

they should be allayed by rest in bed, and the application for a few days of an ice-bag or evaporating lotions to the shoulder. After the first week, the muscles of the shoulder should be gently massaged daily, each séance continuing from fifteen to twenty minutes, for the purpose of minimizing muscular atrophy and joint stiffness. At the beginning of the third week, careful passive motions at the shoulder may be begun, motion being never forced, but only carried each time through such a range as provokes neither pain nor muscular spasm. At the end of the fourth week, the restraining body-bandage should be discarded and active movements begun.

Fractures with displacement at the surgical neck or through the epiphyseal line must first be reduced by traction and manipulation. The peculiar entanglement of the diaphysis in the hollow of the rotated epiphysis, in cases of epiphyseal separation, may require for its relief, as has been pointed out by Moore, that the arm should be carried upward and forward to the perpendicular line, while traction and manipulation are made to bring the fragments into proper apposition. The arm is then to be carefully brought down to the side of the body and dressed as an ordinary fracture. In the rare instances in which the fracture is complicated with dislocation at the shoulder-joint, the dislocation must first be reduced, the dislocated fragment being exposed by incision, and replaced by a combination of pressure and traction through hooks and forceps.

For the further protection and immobilization of the fracture a splint composed of several thicknesses of towelling or canton flannel saturated with plaster of Paris should be moulded to the shoulder and outside of the arm, down to the condyle. This splint should be made to extend well over the top of the shoulder as a cap. Between the inside of the arm and the wall of the thorax should be placed a compress extending up into the axilla, where it should be thickened sufficiently to fill its hollow, but not enough to exert any tension on the axillary muscles. This compress should be fixed in position by adhesive strips, or a turn of bandage encircling the thorax; the arm with its external plastic splint should then be secured to the side of the thorax by a sufficient number of turns of a broad roller bandage, which should in its application begin at the lower part of the humerus and gradually ascend, until it has reached and covered in the shoulder. No attempt to immobilize the elbow-joint should be made, and the anterior half of the forearm is to be supported by a sling, so that the natural extension exerted by the weight of that portion of the extremity below the fracture may not be interfered with. Such readjustments of dressings will be made from time to time as may be required for the comfort of the patient and the continued control of the fracture. Early resort to massage is not so important as in the fractures of the head of the bone, and it usually should be deferred until the third week. Passive movements may be begun at the end of the fourth week, and active movements will be resumed whenever examination shows firm consolidation to have taken place.

Fractures of the shaft of the humerus, the lower limit of the shaft being considered as the beginning of the widening and flattening of the bone about 2 inches above the trochlear surface, may present in differ-

ent cases every variety of break and every form of displacement that may occur in long bones. Direct violence is the most frequent cause, but breaks due to indirect violence are not infrequent, while occasional cases are attributable to muscular strain alone. The character of displacement is determined largely by the direction of the original breaking force, but muscular contraction, also, is active in modifying it, differing in direction and power according to the relation of the seat of fracture to the muscular attachments and to the obliquity of the fracture itself. Injury to the brachial blood-vessels may complicate the fracture, either as the result of the primary violence, or, later, from the pressure of a projecting fragment. Such injury is fortunately rare, but as it may be the cause of gangrene in the distal part of the extremity, its possibility should be kept in mind in cases of crushing injuries of the arm, lest blame for the subsequent unavoidable gangrene should be improperly imputed to the treatment used. In like manner, the principal nerve-trunks may be injured. The musculospiral nerve, from its close relation to the bone through so large a part of its course, is especially exposed to such injury, or is liable later to become enclosed and compressed by exuberant callus.

The *diagnosis* of fracture of the shaft presents no difficulties; the typical signs of fracture declare themselves to the most casual examination.

The *prognosis* should always be guarded, for although in most cases strong consolidation of the fracture occurs as soon as in other long bones, yet failure of bony union is more frequent in this region than in any other part of the skeleton, except the patella. Agnew, in his treatise on surgery, gives the results of a search through literature for reports of cases of ununited fracture. Of the cases collated by him, the more important regions give, of the bones of the forearm, 76 cases; of the thigh, 131; of the leg, 180; of the arm, 219. Various reasons have been suggested in explanation of this special frequency of reparative failure in the humerus, but it is not necessary to go further than defective immobilization, due to common methods of treatment, whereby the lower fragment and the forearm are converted into a continuous long lever, the inevitable frequent movements of whose distal end are transmitted to the point of fracture, and are not controlled by sufficient firmness or extent of grasp of the dressings upon the upper fragment. Some shortening is inevitable in oblique fractures, but of itself is of no importance, since it does not interfere with the normal function of the arm. Rotary displacement is of more importance, but can be guarded against by observing the precaution, when applying the dressings, to see that a line drawn from the greater tuberosity to the external condyle is parallel to the axis of the shaft of the bone.

Treatment.—Reduction of any displacement is first to be secured by extension and manipulation; when the break is attended with extensive bruising of the soft parts, as is not infrequently the case in fracture from direct violence, the patient should be kept in bed, while the arm is supported on pillows and an evaporating lotion kept applied to the injured area until the primary swelling has begun to subside—a period ordinarily of from five to eight days. Meanwhile, the signs of serious injury to blood-vessels or nerve-trunks should be sought for, and, if found, the special treatment indicated for the particular injury resorted

to. If the blood-supply to the distal part of the extremity is found to be compromised, all dressings that may produce constriction or pressure must be absolutely discarded.

Signs of finger- and wrist-paralysis should be carefully sought for both in the primary examination in every case of fracture of the humerus and at the later dressings, for nerve-injury is more frequently occasioned by later pressure from a displaced fragment, or by involvement in the exuberant callus attending imperfect reduction, or by the pressure of the dressings applied, than by the original fracturing force. The rearrangement of dressings to avoid pressure, and whatever procedure may be required to secure a more complete restoration of the proper relations of the fragments, even to incision and suture if necessary, should follow at once the discovery of signs of nerve-pressure. In cases of later imprisonment in callus or cicatricial tissue, the nerve should be relieved by operation at the earliest possible moment.

Immobilization at the seat of fracture at any point along the shaft is best secured by utilizing the wall of the thorax as an internal splint, bandaging the arm to it. The movements of respiration and the unavoidable bendings of the trunk do not create such motion at the seat of fracture as to disturb the progress of repair. Between the thoracic wall and the arm should be interposed a soft compress, which should be graduated in thickness at various parts, so as to fill up the intervening space fully and afford even support to the humerus. To the outside of the arm, from shoulder to elbow, should be moulded the plaster-of-Paris splint described in the preceding section. In cases of fracture at the middle of the shaft, a coaptation splint of wood, long enough to reach from axilla to condyle, and of a breadth slightly exceeding the diameter of the arm, well padded with cotton wool, should be adjusted to the inner side of the arm, and secured in place by three strips of adhesive plaster made to encircle the external plaster splint. The arm is now to be bandaged to the side of the thorax by a roller which, beginning just above the elbow, gradually ascends with successive turns until it has enclosed the shoulder. The forearm should then be brought in front of the chest at a slightly acute angle, the comfort of the patient being consulted as to the exact position, and fixed in place by a separate roller, which should cover in only the anterior half of the forearm. By this dressing the elbow is left uncovered, any tendency to press the lower fragment upward is avoided, and the use of the weight of the forearm for continuous extension is in some degree preserved. Should marked shortening persistently recur after reduction, this natural extension force can be increased by slinging such amount of weight from the elbow as may be necessary to overcome the tendency to shortening. In fractures through the lower third of the shaft, the lower fragment is apt to be tilted forward by the action of the triceps muscle and the weight of the forearm. To overcome this tendency it is necessary to place the elbow at a more acute angle for the first two weeks.

Non-union.—Should firm union fail to be secured by the treatment described by the end of six weeks, massage and hammering over the site of the fracture may be applied twice each week, the immobilization of the parts being maintained in the intervals. If, after from four to

six weeks of this special treatment, union is still delayed, the fracture should be exposed by suitable incision in the long axis of the limb, and the ends of the bones freshened and dovetailed into each other and fastened together by heavy silver-wire sutures. A more exact retention of the bone-ends in apposition can be secured by the device of White, who used a steel plate $\frac{3}{4}$ inch wide and 3 inches in length, pierced by two screw-holes in each half. This plate is placed upon the surface of the apposed denuded bone-fragments, and secured by screws which are driven into holes in the bone made by a drill. At the end of six or eight weeks, the soft parts are again divided sufficiently to enable the surgeon to remove the screws and withdraw the plate. In all these procedures special care is required to avoid injury to the main vessels and nerves of the arm.

Fractures of the lower extremity of the humerus are of frequent occurrence, both from the direct force of falls upon, or blows received by, the elbow, and the indirect force of falls upon the outstretched hand. They are especially frequent during childhood. The line of fracture may extend transversely above the condyle or through the epiphyseal line in young subjects; it may be limited to the chipping away of a small fragment of either condyle, or the fracture may separate the entire mass of the condyle and open into the cavity of the elbow-joint. By the comminution of the lower fragment a transverse supracondyloid fracture may communicate with the elbow-joint through a longitudinal line of fracture (Fig. 235). Dislocation of the ulna or radius at the elbow is a not infrequent complication; and fracture of the upper end of the radius or ulna is an occasional concomitant of any of the above-mentioned fractures of the humerus, the injuries being the result of severe crushing violence, and often compound in character.

FIG. 235.—Supracondyloid transverse fracture of the lower end of the humerus, with longitudinal fissure into the elbow-joint (T-fracture).

The involvement of the elbow-joint, either directly or indirectly, gives especial gravity to fractures of the lower end of the humerus. Some limitation of the motions of this joint is the rule after fracture in its vicinity, and complete ankylosis is not infrequent. The exact retention of the fragments in their proper positions is difficult to maintain, owing to the leverage of the bones of the forearm with which the lower fragment remains attached; and slight displacement is enough to alter materially the symmetry of the elbow, and often to impair its function by occasioning a mechanical obstacle to the full normal range of motion. Even in the absence of malposition, new-formations of bone from exuberant callus

may produce the same effect, or may absolutely ankylose the joint. Some thickening and contraction of the capsular and peri-articular tissues, as the immediate result of the injury, is usual and unavoidable; and when true inflammation is provoked by infection or repeated traumatism, permanent contractures and adhesions, that may produce a prolonged or even definitive limitation of motion, are likely to result.

Oblique fracture of a condyle, the line of fracture entering the joint, is the most common variety of fracture. Both condyles seem to be about equally exposed to fracture. The direction of the line of fracture separating the *internal condyle* is a fairly uniform one, beginning

FIG. 236.—Fracture of the internal condyle (Hamilton).

FIG. 237.—Fracture of the external condyle (Hamilton).

FIG. 238.—Fracture above the condyles, with longitudinal fissure into elbow-joint (Hoffa).

somewhat above the base of the epicondyle, and extending obliquely outward and downward through the olecranon and coronoid fossæ to the center of the trochlear surface. The contractions of the triceps and brachialis anticus muscles upon the ulna tend to pull it and its attached condyloid fragment upward as far as the attachments of the radius will allow. This tendency to upward displacement is increased by any pressure upon the under surface of the olecranon or by lateral movements of the forearm internally. Some rotation of the condyloid

FIG. 239.—Gunstock deformity at elbow, following fracture of either condyle of the humerus (Allis).

fragment with anterior displacement is caused by extending the forearm. The effect of any upward displacement is to lessen the normal humero-ulnar angle and to convert it into an abnormal one in the

opposite direction, producing the deformity, familiar by its frequency, called the "gunstock" deformity, shown in Fig. 239.

The *external condyle* may be detached by a line of fracture that enters the joint at some point of the capitellum, or that extends more internally to the trochlea. The extensor and pronator muscles that arise from it tend to pull it forward and downward, while the mobility of the condyle permits internal lateral deflection of the forearm at the elbow, producing again loss of the normal humero-ulnar angle and the gunstock deformity.

In *supracondyloid transverse* fractures, the lower fragment is usually displaced backward and is drawn upward behind the lower end of the upper fragment. The deformity simulates very closely that produced by backward dislocation of the bones of the forearm at the elbow, and

FIG. 240.—Supracondyloid fracture of the humerus, lower part displaced backward; epiphysis of the olecranon indicates the youthful age of the patient (Morton) (skiagraph by Goodspeed).

in the presence of swelling and muscular rigidity requires careful examination for its discrimination.

The line of separation may follow the epiphyseal line, in which case the fragment formed by the epiphysis may still more readily escape recognition by reason of its thinness. The replacing of the fragments in their proper relations to each other is easily accomplished by extension and manipulation while the elbow is flexed at a right angle, but the displacement tends at once to recur as soon as the retaining forces are removed. Union may take place with the fragments incompletely reduced, causing a permanent mechanical obstacle to the full flexion of the elbow. Rotary displacement of the lower fragment, induced by the leverage of the forearm bones, may readily occur, unless care is taken to avoid it in the course of treatment. Supracondyloid fracture with comminution of the lower fragment results from violence of special

severity, and is often accompanied by lacerations of the overlying soft parts, that expose the fracture to septic infection. Even in the absence of infection, the effusion into and about the joint is extreme in amount, the development of callus is especially liable to be excessive and so placed as to interfere with the function of the joint, and the difficulties attending the proper reduction and retention in place are so great that marked deformity is often unavoidable.

FIG. 241.—Supracondyloid fracture of the humerus (Hoffa).

The tip of either condyle may be chipped off by a direct blow, and may become displaced downward by muscular traction. The line of fracture does not involve the joint, nor does the displacement impair function. The injury is a relatively insignificant one.

The *diagnosis* of fractures at the lower end of the humerus requires for its satisfactory establishment careful and minute comparison of the anatomical landmarks of the region. These are often obscured by the great swelling that quickly follows injuries at the elbow, and their satisfactory examination can often only be done under general anesthesia, especially in the cases of children, in whom most of these fractures occur. Supracondyloid fracture is to be distinguished from backward dislocation of the ulna and radius by the unchanged relations of the condyles and the olecranon, by the recognition of the irregular outline presented by the projecting surfaces of the displaced fragments, by the shortening of the humerus, proven by measurement from the tip of the acromion to the condyle, by the facility of reduction followed by tendency to redisplacement, and by the crepitus elicited when the fragments are brought down into place. The presence and location of oblique condyloid fractures is best determined by grasping the lower end of the humerus by the fingers of one hand, and with the other rocking the bones of the extended forearm from side to side; the broken-off condyle is felt to move with the bones of the forearm, producing a lateral mobility at the elbow, which is never present in the normal condition of the joint. Crepitus is elicited by these maneuvers, and the presence and extent of displacement are appreciated by palpation.

In the *treatment* of all fractures at the lower extremity of the humerus, accurate and speedy reposition of the fragments is of high importance. This can usually be readily effected by manipulation and extension while the elbow is flexed at a right angle, in which position the most general relaxation of the tissues in and about the joint is present. As to later retention, this position has the disadvantage that the relaxed tissues favor consecutive renewed displacement, which may be caused by the mere pressure of dressings and the weight of the

extremity supported in the customary sling, even in the absence of muscular contraction and deviations of the bones of the forearm from their proper axis. By placing the forearm in the extended position the humero-ulnar angle can be kept under control; but some anterior rotation of a condyloid fragment is inevitable, and some posterior and rotary displacement of the lower fragment in cases of supracondyloid fracture is difficult to prevent, the probabilities of later functional impairment of the joint are increased, and in cases of ankylosis the position of the joint is the most objectionable that could be produced. H. L. Smith has shown that in all cases of fracture of the lower extremity of the humerus, the position in which the fragments are held most firmly in place and are least susceptible to displacement from forces acting from without is that of flexion at an angle as acute as the comfort of the patient will allow. In this position the fragments are all held locked between the coronoid process in front and the ligamentous and musculotendinous structures behind. Unless proper adjustment of the fractured surfaces has been secured, full flexion at the elbow cannot be made, so that it is essential that this adjustment be first secured before attempting to bring the forearm into the acute flexion required. The fragments having been adjusted and the forearm, semi-prone, brought up into full flexion, it remains only to hold the forearm in this position by a broad figure-of-8 bandage around the elbow and body, as shown in Fig. 242. No further retentive dressing is required. Should the acuteness of the flexion be found to be so sharp as to interfere with the distal arterial supply, or should it become painful on account of later swelling, the angle must be made greater; otherwise, the original position should be maintained until consolidation of the fracture is well advanced. In cases of open infected fracture, the same position should be maintained, abundant access to the elbow for the necessary special dressings being afforded. In the latter case, before final consolidation has supervened, in view of probable ankylosis, the forearm should be dropped to the angle most convenient for the future usefulness of the hand. Should, for any reason, the position of acute flexion described be found to be intolerable or inadvisable, the forearm may be brought down to the position of a right angle and immobilized by a plastic splint, preferably of canton flannel or similar material saturated with plaster-of-Paris cream, moulded to the anterior surface of the arm and forearm, reaching from axilla to wrist, and embracing two-thirds of the circumference of the limb. An angular, narrow strip of metal should be incorporated in this splint to reinforce it.

FIG. 242.—Figure-of-8 elbow bandage for immobilizing forearm, with acute flexion of elbow (Lund).

No essay at passive motion should be made before the fourth week, and even then it should be restricted to that range of motion which can be made without the use of force and without causing pain. Earlier and forcible attempts at mobilization disturb the adjustment of the fragments, increase the amount of callus-formation and of the inflammatory exudation into and about the joint, and exaggerate the danger of ultimate permanent ankylosis. By the sixth week all dressings may usually be laid aside and active use of the extremity be resumed. The moderate stiffness generally present gradually disappears spontaneously within a few weeks. If an ankylosis due to newly formed bands of adhesion is found to persist, later forcible rupture under ether must be done. Masses of excessive callus or bone-fragments healed in malposition, interfering with the useful motion of the joint, call for incision and the chisel for their removal.

The Bones of the Forearm.—Fractures of the bones of the forearm fall naturally into three groups: 1. Those in the vicinity of the elbow; 2. Those involving the shaft of one or both bones; 3. Those at the wrist. Of the first group, the most frequent injury is fracture of the olecranon process of the ulna, more rarely that of the head or

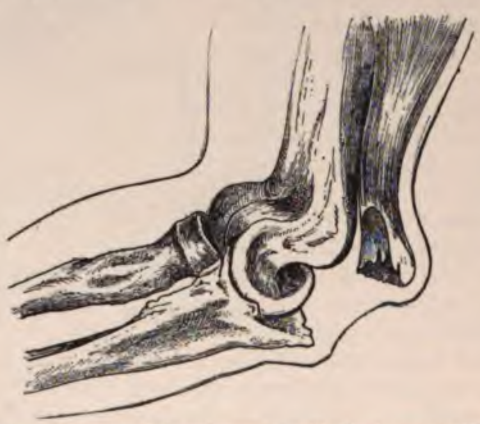

FIG. 243.—Fracture of the olecranon, with displacement (Hoffa).

neck of the radius, and still more rarely that of the coronoid process of the ulna. Combination of one or more of these fractures with fracture of the lower extremity of the humerus, or with dislocation at the elbow, is occasionally met with.

The **olecranon** may be fractured either by direct force applied to the point of the elbow, or by cross-breaking strain exerted through the forearm as a lever while the triceps is in tense contraction.

The liability to displacement of the upper fragment by the contractions of the triceps muscle will depend upon the extent to which the tendino-aponeurotic fibers, which closely invest the process, are lacerated. When these are freely torn, the bone-fragment may be drawn upward to the extent of an inch or more, the displacement being increased by flexion of the joint. Fractures by direct force present the least degrees of aponeurotic laceration, and as a class the least dis-

placement. Whenever there is much separation of the fragments, their fracture-surfaces become more or less fully invested by a fringe-like apron of the stretched and lacerated aponeurosis which has dropped down into the gap and remains as an obstacle to full coaptation and osseous union.

The *symptoms* produced by the injury are diminution or loss of the power of extending the forearm, with pain and tenderness at the point of injury, mobility of the detached fragment when manipulated by the surgeon, and deformity in many cases caused by the upward displacement of the detached fragment, leaving a gap where the point of the elbow should be, as shown in Fig. 243. Crepitus may or may not be elicited, according to the absence or presence of fibrous tissue between the fragments when they are brought together. More or less ecchymosis early declares itself, together with marked effusion into and about the elbow-joint. The prominence of the process and its subcutaneous position render the diagnosis of its fracture easy. The repair, when the fracture is not open and infected, ordinarily progresses without special complication. The swelling subsides promptly, and union may be secured by the fourth week, with fair restoration of function after the disappearance of the peri-articular rigidity; some limitation to full normal extension is an occasional permanent sequel. Bony union is frequently prevented by the interposition of fibrous material between the fragments (Fig. 244).

FIG. 244.—Fracture of the olecranon, with fibrous union (Anger).

In the *treatment*, if the fibrous attachments of the fragments are sufficiently intact to hold them together, so that the upper fragment is not separated from the lower in moderate flexion, the limb may be immobilized in the partly flexed position, which will be greatly to the comfort of the patient. If, however, such flexion separates the fragments, or the upper fragment is already drawn upward, the forearm must be kept extended until consolidation has become firm. The extended position alone is usually sufficient to bring the fragments into apposition. If position fails to bring the fragments together, it has been recommended to attempt to pull the upper fragment down, and hold it in place by a strip of adhesive plaster so applied to the skin above it that downward traction may be made by the two ends of the plaster, which are then secured to the front of the forearm below. Such a device has, however, but little control over the underlying bone-fragment unless it so completely encircles the limb that it unduly constricts it, and inevitably so aggravates the local congestion and exudation into and about the elbow-joint as to endanger its later function more than would the formation of the fibrous union which

it is intended to prevent. It is better, if the fragment cannot be kept down in place by position, that the fracture should be exposed by incision, and accurate coaptation secured by sutures after the removal of all fibrous tissue and blood-clot from the face of the fracture-surfaces. Usually it will be possible to bring and hold together the fragments by chromicized catgut sutures applied to the periosteum and tendino-aponeurotic coverings only. Should these

FIG. 245.—Greenstick fracture of the shaft of the ulna, with fracture through the epiphyseal line of the head of the radius, and marked displacement outward of the upper end of the diaphysis of the radius, simulating dislocation of the head of the radius (skiagraph by Stewart).

prove insufficient, silver-wire sutures may be inserted through the bone-substance. If the fracture is already exposed by a wound, suturing is indicated as a routine, coupled with abundant provision for free primary drainage, which will have to be prolonged should infection not be escaped. As in other joint-fractures, such effusion into the joint and swelling of the surrounding tissues may supervene as to require that treatment at first be limited to placing the limb in as comfortable a position as possible upon a pillow and applying to it evaporating lotions, or a bag of ice, until the primary local reaction has subsided.

For immobilizing the elbow during repair, a well-padded splint is to be adjusted to the anterior surface of the forearm and arm, and secured by a roller bandage. By the end of the fourth week the splint may be dispensed with, and massage and movements instituted.

The coronoid process may be chipped off by being driven against the articular surface of the humerus in the act of a dislocation backward of the ulna. Such injury is infrequent. Still more rarely this process has been found to have been torn away as a part of the injury resulting from a crush of the elbow. The fragment will usually retain sufficient attachments, through untorn periosteal and tendinous fibers,

FIG. 246.—Fracture of radius and ulna near their lower end; anteroposterior view. Epiphyseal cartilages especially distinct, outlining the lower epiphyses (Warren). For lateral view of same injury, see Fig. 247.

FIG. 247.—Fracture of bones of the forearm near their lower extremity, with posterior displacement of the lower fragment (Warren).

to prevent much displacement. If examination is made before much swelling has supervened, it may be appreciated as a movable mass at the bend of the elbow, by the manipulation of which crepitus may be elicited. In cases of coexistent dislocation, the dislocation is readily reducible and as readily recurs. Repair by bony union is to be expected under proper treatment. The treatment required is fixation of the elbow in acute flexion, as already described for the injuries involving the lower end of the humerus.

The head of the radius may have more or less of its articular rim split off by the same forces as have just been mentioned in connection with the coronoid process of the ulna; the two injuries may occur coin-

cidently. The special symptoms to which this injury gives rise are pain and crepitus, caused by efforts at rotation. In some cases the detached fragment has been appreciable as a movable piece lying between the olecranon and the head of the radius.

The line of fracture may be more or less transverse through the neck of the radius, or through the epiphyseal line in young subjects (Fig. 245), in which case, in addition to pain and crepitus on rotation of the forearm, anterior displacement of the upper end of the lower fragment from contraction of the biceps muscle may be sufficient to cause a noticeable projection. Fracture at the upper end of the radius may

FIG. 248.—Fracture of bones of the forearm, with angular displacement (Warren).

readily be followed by total loss of the power of rotation, from obstruction caused by the fragment healed in displacement, or from welding together of the radius and ulna by vicious callus. The treatment required is immobilization in the flexed position.

The bones of the forearm along their shaft are the frequent subjects of fracture, both from direct violence and from the indirect force of falls upon the hand. Instances of fracture from muscular action alone have been reported. Incomplete or greenstick fractures are met with more frequently in these bones than elsewhere, with the possible exception of the clavicle. All the varieties of fracture to which long bones are liable may be presented by the bones of the forearm (Fig. 246).

Displacement, angular or by overriding, is common. Lateral dis-

placement from pressure of dressings or muscular contraction may cause such encroachment upon the interosseous space as to limit rotation, or by the welding together of the two bones to destroy it altogether

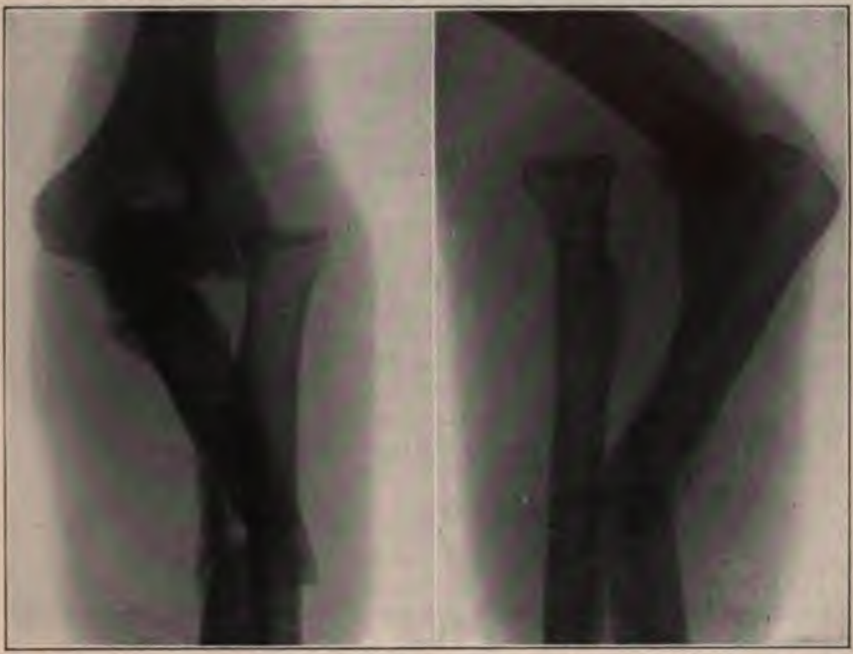

FIG. 249.—Compound fracture of the ulna, with dislocation of the head of the radius (Goodspeed).

(Fig. 250). When the point of fracture in the radius is located above the insertion of the pronator radii teres muscle, the upper fragment is liable to become supinated by the unopposed action of the biceps, requiring the whole forearm to be kept in supination until consolidation is secured, to avoid the loss of function from the rotary displacement.

FIG. 250.—Fracture of the radius and ulna, with exuberant ossified callus uniting the two bones (Warren Museum).

The *diagnosis* presents no difficulties, owing to the superficial position of the bones and the readiness with which the characteristic symptoms of fracture may be elicited.

The *course* of the healing, as a rule, is uncomplicated and leads to full bony union in from four to six weeks. The presence of comminution or of open wound with infection may interfere with such a favorable

progress, and may determine either non-union or such muscular atrophy and adhesions along tendon-sheaths as to cripple the limb seriously. Many instances have been recorded in which, by the pressure of encircling bandages, or of splints applied without proper provision for later swelling of the parts or left without intelligent inspection, gangrene of the distal portion of the limb or troublesome sloughs from local pressure have been produced.

Treatment.—Accurate reduction is important, both for the preservation of the symmetry of the limb and for the power of normal rotation. This is to be accomplished by extension and manipulation while the forearm is held in the position in which its muscles will be most relaxed —viz., midway between pronation and supination, with moderate flexion of elbow and wrist. After reduction, the fragments should be held in position by two light wooden splints, one to the dorsal and one to the palmar aspect of the forearm. Each should be well padded with cotton, and should be broad enough to prevent the encircling bandage that holds them in place from making any lateral pressure on the forearm. The dorsal splint should extend from the point of the elbow to the metacarpophalangeal joint; the palmar one from the flexure of the elbow to the flexure of the wrist. These splints should be first fixed in position by two strips of adhesive plaster wrapped about them, one near either end; then a roller bandage should be applied firmly over all. Finally, the forearm should be placed in a sling. Frequent inspection of the limb should be made daily for the first week, to guard against the effects of pressure or the possibility of displacement from loosening of the dressings. Usually by the fifth week the splints can be dispensed with and active use of the limb resumed.

Either the **radius** or the **ulna alone** may be broken at any part of its shaft by a direct blow. Such an injury is not uncommon. The extent and direction of the displacement, if any occurs, is determined by the fracturing force. The treatment required is the same as that already described in case of fracture of both bones. The tendency of the biceps muscle to rotate the upper fragment of the radius into supination, when that bone is fractured above its middle, is to be kept in mind, and accommodated in such case by dressing the forearm in supination until consolidation has been secured.

The bones of the forearm in the immediate vicinity of the wrist-joint may be fractured by a direct crushing force. Such injuries are apt to be accompanied with wound of the overlying soft structures, and to present such varying degrees of comminution and displacement as to negative systematic description.

Fracture by indirect force transmitted from the hand is of frequent occurrence. In many cases the lower end of the radius only is fractured, but not infrequently the styloid process of the ulna is also broken off, and in some cases the shaft of the ulna is fractured at a point some distance above. The frequency with which the force of a fall is broken by an outstretched hand causes fracture of the radius at its lower end to be the most common of all fractures. The peculiar mechanism of the wrist-joint is such as to give to these fractures, as a class, a quite uniform type; the proximity of the intricate and important radio-ulnar and radio-carpal articulations and the numerous tendon-sheaths of the flexors and

extensors of the wrist and hand entail special liability to functional disability from adhesions resulting from the accident, while whatever deformity may result is kept in constant view by the superficial and prominent position of the bones.

The lower extremity of the radius, whenever strong backward or forward flexion of the hand upon the forearm occurs, is subjected to cross-breaking strain through the common carporadial ligaments, anterior or posterior, as the case may be. The frequency with which the force of a fall is partially sustained by the outstretched hand, and the hand thereby forced into strong backward flexion, explains the frequency of the fracture in question. Fig. 251 shows the relations of the lower end of the radius to the elements of the wrist-joint when the hand is bent backward until the anterior ligaments are taut. Further strain, if sufficiently violent, must rupture either the ligamentous fibers or the bones of the carpus, or tear off some portion of the lower end of the radius. The projection of the anterior articular lip of the radius, into which the ligament is inserted, mechanically favors the transmission of the greater part of the strain to that portion of the bone, and renders it less liable to resist than are the fibers of the ligament itself.

The manner in which the resulting fracture is produced is shown in Fig. 252.

FIG. 251.—Diagram showing the relations of the lower end of the radius to the elements of the wrist-joint; longitudinal section with the hand in moderate backward flexion.

FIG. 252.—Effect upon the lower end of the radius of the cross-breaking strain produced by extreme backward flexion of the hand.

The amount of the bone thus torn off varies greatly in different cases, on account of the differences in the shape and structure of the bone, in the relative strength of the different fasciculi of the ligament, and in the amount of strain and pressure in action. The accompanying illustrations, drawn (Figs. 253, 254) from museum specimens, show some of these varying lines of fracture.

In most cases of falls upon the outstretched hand the cross-breaking strain from the backward flexion of the hand is further complicated by a vertical force, due to the impact against the ground of the weight of the body, transmitted through the limb to the hand. The amount of this in different instances must vary within very wide limits, depending upon the weight of the particular body and the distance and velocity of the fall. An equal amount of this force will also produce different

effects in different individuals, and in the same individual at different times. In many instances, a cross-breaking strain to the point of fracture at the wrist is successfully resisted by the tissues, and the composite strain is transmitted higher along the limb, to be decomposed ulti-

FIG. 253.

FIG. 254.

FIGS. 253, 254.—Lines of breakage in fractures of the lower extremity of the radius.

mately without serious injury, or to produce dislocation or fracture at some other point.

Whenever, however, the tearing away of more or less of the lower end of the radius has resulted, the effect of the surviving vertical force is to thrust backward and upward the fragment that has been torn off,

FIG. 255.—Fracture of the lower extremity of the radius (Warren).

and to impale it upon the sharp, strong edge presented by the thick compact tissue of the posterior surface of the upper fragment.

The amount of backward displacement thus produced may be of any degree, from a slight slip, merely sufficient to efface the natural projection of the anterior articular lip, to dislocation so complete that the whole of the lower fragment overrides the lower end of the upper.

The degree of impalement suffered by the lower fragment is also subject to the widest variations, from that of a slight mutual entanglement of the irregular fracture-surfaces, to that of deep penetration of the upper into the lower, with splitting of the lower into many fragments. Even in its minor degrees, this interpenetration of the fragments, by the crushing of the cancellous tissue of the lower fragment which attends it, produces some positive change in the form and structure of the lower fragment, which is essentially a mass of spongy tissue enclosed in a thin, compact shell. As the result of this, some permanent alteration from the normal contour of the bone is inevitable (Fig. 256), with a more or less marked deformity of the

FIG. 256.—Showing change in contour of the lower fragment, alteration in direction of the articular facet, and loss of projection of the anterior lip consequent upon fracture of the lower extremity of the radius (adapted from Anger).

region following. Even though the fragments are disengaged from one another, and put in their proper position, the lower fragment remains shortened, the direction of its articular face is changed, and, according to the degree of the comminution, it is broadened both laterally and anteroposteriorly. By the backward displacement of the lower fragment of the radius further important changes in the relations of the other constituents of the wrist-joint are produced. The torn-off fragment with the attached carpus is forcibly rotated into supination. The radio-ulnar ligaments are strained, possibly in part ruptured, and the lower end of the ulna is made to project abnormally upon the front and ulnar side of the wrist. The further strain of the continued dorsal flexion falls especially upon that strong fasciculus of the anterior common ligament which passes obliquely from the middle of the carpal mass to the side and base of the styloid process of the ulna. As a result, the projection of the ulna is intensified, and, in many cases, the styloid process itself is torn off by the strain. As long as the displacement of the radial fragment is unreduced, the carpus remains locked in the position of supination, and the anterior projection of the head of the ulna is perpetuated by the continued tension of this fasciculus. When the hand is taken up from the ground and allowed to recover from its position of dorsal flexion, a characteristic deformity of the wrist is presented (see Figs. 257, 258), due to the posterior projection of the carpus and lower radial fragment, the anterior projection of the lower end of the upper radial fragment, and the antero-internal projection of the head of the ulna. Dissection of the parts in this state shows that the periosteal and aponeurotic

structures that were stripped up from the back of the proximal radial fragment, instead of being torn across, constitute now a strong band, which is made tense by the forward flexion of the wrist, and while thus tense tends to hold the fragments in impaction and hinders their sepa-

FIG. 257.

FIG. 258.

FIGS. 257, 258.—Deformity at the wrist consequent upon displacement backward of the lower fragment of the radius after fracture at its lower extremity (Levis).

ration by traction and ready reposition by pressure. If union occurs without complete reposition of the lower fragment, the space which is left between this detached periosteal layer and the posterior surface of the bone becomes filled with plastic material, which, by subsequent

FIG. 259.—Fracture of the lower end of the radius, with anterior displacement of the lower fragment united in deformity (from specimen in the Museum of the Edinburgh College of Surgeons) (Roberts).

ossification, so encases this portion of the radius in new bone that, upon subsequent section, it presents the appearance of deep penetration of the lower by the upper fragment.

Anterior displacement of the lower fragment, after fracture of the lower end of the radius, is occasionally met with, as shown in Fig. 259.

This particular form of injury has been recently minutely studied by Roberts, who has assembled a considerable number of clinical histories and museum specimens illustrating it. In a large proportion of these cases, the injury was known to have been occasioned by falls upon the back of the hand, and may be referred to a cross-breaking strain exerted through the posterior common ligament of the wrist upon the lower end of the radius, by the hand thrown into extreme palmar flexion. In a well-marked case, seen by myself, the patient had fallen backward out of a wagon to the ground. The rarity of falls upon the back of the hand, and the absence of any posteriorly projecting articular lip to exaggerate the force of strain exerted through the ligament, explains the relative rarity of this form of displacement.

The effect of the direct impact of the carpus, violently driven against the broad, shallow, saucer-like articular surface of the radius, is also to add a direct crushing and splitting force to the indirect cross-breaking strain heretofore considered. By this direct force the posterior lip may be crushed off, or stellate lines of fracture may be

FIG. 260.

FIG. 261.

FIGS. 260, 261.—Showing the crushing and splitting effects of direct impact of the carpus against the lower articular surface of the radius.

created, radiating from a central point of the articular surface, comminuting the lower fragment, if a transverse fracture coexists, or in other cases extending upward as longitudinal crevices for a variable distance along the shaft, without transverse fracture (see Figs. 260, 261).

The injuries sustained by the soft tissues about the wrist-joint, coincident with the bone-lesions that have been described, are extensive and important. The ligaments are violently stretched, partially lacerated, and sometimes entirely ruptured; the synovial sacs of the articulations are badly contused, sometimes lacerated and filled with blood; the sheaths of the tendons are injured, both in front and behind—in front, the projection of the ragged edge of the upper fragment into the midst of the flexor tendons may lacerate their sheaths and irritate the tendons; behind, the violent stripping up and continued tension of the periosteum is an injury done to the floor of those extensor tendon-sheaths into the formation of which it directly enters.

Effusions of blood and lymph into the anterior tendon-sheaths and adjacent connective-tissue spaces early produce a well-marked swelling on the front of the wrist, above the annular ligament, which exaggerates the deformity formed by the bone-displacement, and may simulate displacement when none exists. Such an effusion-tumor may result from injury to the soft parts alone, without the presence of any lesion of the bone. On the back of the carpus also, some swelling of similar character forms, as a rule. These effusions are firm, are slowly absorbed, especially in the feeble and aged, and tend to provoke the formation of adhesions along the course of the tendons which they envelop.

The *diagnosis* is usually to be made from the deformity present rather than from the recognition of crepitus and abnormal mobility, which often are not to be elicited, on account of the displacement and impaction and the resistance of untorn fibrous connecting bands. In cases in which the degree of displacement, and consequently the extent of deformity, is but slight, careful palpation will usually enable the surgeon to recognize the loss of the projection formed by the anterior lip of the sound bone and some abnormal elevation of the lower fragment on the back of the wrist. In the absence of any appreciable displacement, the lesion of the bone may still be inferred, if pressure elicits a point of special tenderness on the outside of the radius, near the base of the styloid process, since such tenderness at that point could not result from any ligamentous rupture. Forward displacement of the head of the ulna is recognized at once on inspection of the wrist, and, when present, indicates the coexistence of fracture of the radius. Fracture of its styloid process is indicated by special tenderness at its base; manipulation may elicit undue mobility and crepitus, but it is rarely so completely torn away as to become notably displaced.

Fracture without great displacement is often overlooked, and, being regarded as a simple sprain, is permitted to heal without effort to prevent deformity. In cases of severe injury to the wrist, accompanied with ecchymosis, local swelling, and impairment of function, the presence of fracture is always to be inferred, and only the failure to elicit any of the signs of it that have been mentioned should warrant the conclusion that it is absent.

Fracture with extreme displacement may be mistaken for a dislocation of the carpus—an error which was universal until within the present century. Such uncomplicated dislocation is an extremely rare occurrence, and should be accepted as present only when careful examination has demonstrated beyond question that the radius is intact.

Prognosis.—Rapid bony union is the invariable rule, but the impairment of the function of the wrist is often slowly recovered from, and in some cases the adhesions among the peri-articular structures, especially along the tendon-sheaths, are so dense that for many months the wrist remains rigid and the movements of the fingers are limited. The amount of actual deformity that remains will depend largely on the success of the efforts to secure primary accurate reposition of the displaced fragment. In a considerable proportion of cases, however, there

has been occasioned by the injury such actual alteration in the form of the lower fragment that the restitution of the perfect normal contour of the part is impossible by any treatment, and some deformity is unavoidable. The involvement of the epiphyseal cartilage in the fracture in children has been known to induce premature ossification and arrest of growth of the lower end of the injured bone, with later gradually increasing deformity, from its shortness relative to its fellow ulna. The most common alteration, as the result either of incomplete reduction or damage to the bony structure, is the loss of the anterior projection of the articular lip and the imposition of a more or less backward inclination upon the plane of the articular surface (Fig. 262). The consequence is a perpetuation in some degree of the deformity which has already been described as characteristic of the primary injury. The inward and forward projection of the lower end of the ulna in many cases persists, often when there is no appreciable deformity of the radius, owing to the permanent elongation of the ligaments which bind it to the radius, although in some cases coexisting minor changes in the shape of the radius may be concealed by the overlying tissues.

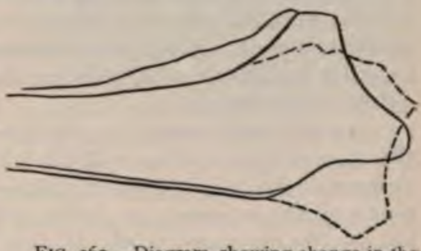

FIG. 262.—Diagram showing change in the contour of the lower end of a radius after healed fracture; dotted line shows the original normal contour.

The bony deformity, even when marked, of itself entails very little, if any, functional disability. The articular rigidity, the matting of tendons, and the contracture of ligaments and fibrous bands, due to the lacerations and irritations of these structures in connection with the bony injury, the persistence of the exudates that follow, and the effects of prolonged immobilization, produce the chief sources of disability following this injury. This disability is particularly prone to be marked and persistent in elderly persons, but usually ultimately yields, even in these, to patient efforts at massage and mobilization.

Treatment.—If displacement exists, its accurate reduction is of the first importance. The chief obstacles to ready and perfect reduction are the impaction or entanglement of the uneven surfaces of the fragments, and the tension of the untorn periosteofibrous band that still unites them at the back. The latter can be overcome at once by placing the hand in dorsal flexion; while the hand is still in this position, extension will disengage the fragments, and firm thumb-pressure upon the back of the lower fragment will push it forward into place. If the hand is then brought into palmar flexion, the fracture-surfaces fall together and the normal contour of the bone is restored, the carpo-ulnar ligament is relaxed, and the ulna assumes or may be pressed up into proper position in relation to the radius. Should the first effort to secure perfect reduction be unsatisfactory in its results, renewed and more thorough attempts should be made, until it is evident that the best possible position of the fragments has been secured.

Ordinarily, there is but little tendency to renewed displacement after reposition, providing the part is protected from further direct force.

Any pressure on the anterior surface of the wrist will bear upon the projecting anterior lip of the lower fragment, and may crowd that fragment back to the plane of the shaft of the bone. Anteroposterior pressure also tends to crowd the soft tissues in between the radius and ulna, and, forcing the ulna away, to renew and perpetuate its diastasis. The first indications are to give the injured part support and protection, and by immobilization and equable compression to limit effusion and promote repair. With the subsidence of the primary wound-reaction, especial precautions to maintain the mobility of the wrist- and finger-joints are indicated.

In very many cases the application of a flannel roller bandage and the support of a sling will be all the apparatus required. A small compress, about $\frac{1}{4}$ inch in thickness, should be first adjusted upon the front of the forearm, its lower edge being permitted to come down nearly, but not quite, to the level of the anterior lip (Fig. 263, *a*). Over

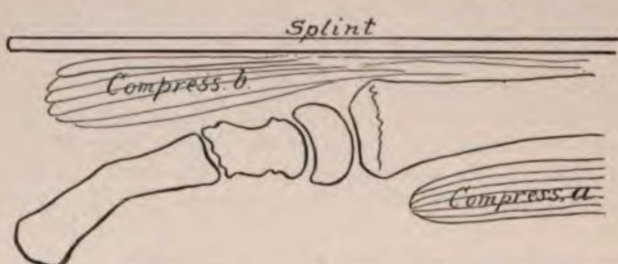

FIG. 263.—Diagram showing the arrangement of compresses and splint best adapted to retain fragments in proper position after reduction.

this the roller passing, binds the strained and shattered parts of the wrist together and gives an agreeable sense of security and support.

This circumferential compression is especially important to maintain the lower fragment and the carpus in their proper position to the ulna. It is further reinforced during the after-treatment by keeping the forearm supported on its ulnar side in a narrow sling, which does not extend forward beyond the distal end of the ulna, in which position the weight of the unsupported hand and wrist is an additional force tending to press the ulna into position. At this first dressing, allowance must be made for the primary traumatic swelling that follows the injury, and the bandage must later be loosened or cut, if its constriction becomes a source of discomfort. As the swelling subsides, it should be tightened again.

Whether to this dressing should be added a splint will generally depend upon what may be called collateral circumstances. In cases of those who are quite young, or are careless, or are apprehensive, the additional protection of a splint is a wise precaution, if the surgeon also remembers that its prolonged use may create finger- and wrist-stiffness, and that by its pressure deformity may be perpetuated. For a young surgeon also, it will in most cases be more discreet not to disregard the popular sentiment as to the necessity of a splint in the treatment of a fracture.

Many special forms of splints have been devised by surgeons for this

injury. Not one of them possesses such special advantage as to justify its description here. A light, straight splint, such as can be extemporized anywhere from a pine shingle or a cigar-box, answers the indications perfectly. Only one splint should be used, and this should be applied to the dorsum of the wrist and forearm (see Fig. 263). It should not be wider than the wrist itself; it should extend below only to the heads of the metacarpal bones, so that the fingers shall not be confined by it; it should be well padded, and the padding should be made thicker over the carpus and metacarpus, so as to keep the hand in slight flexion while it is in place; it should be secured with a roller to the hand and forearm, and the forearm then suspended in the narrow sling already recommended. From the third day the thumb and fingers should be frequently and systematically flexed, and after the first week the splint should be daily removed and the wrist massaged and moved. By the end of the third week, the splint should be discarded altogether, and thereafter active and passive movements of the wrist and fingers, with massage, ought to be practised systematically until the normal function of the parts has been restored.

Bones of the Wrist and Hand.—One or more of the **carpal** bones is occasionally broken by direct violence; more frequently the

FIG. 264.—Fracture of the metacarpal bone (Warren).

carpal lesion is a minor incident in the midst of an extensive crushing injury of the wrist. Fracture of the scaphoid, the semilunar, or the os magnum has in different instances been noted as a complication of a fracture of the lower extremity of the radius. In the absence of noticeable displacement, a fracture of a carpal bone may easily be overlooked, the symptoms of contusion and sprain being so marked as to obscure the possible signs of the fracture.

In the *treatment*, after any displacement has been corrected by pressure, the subsequent care should be conducted on the lines already

laid down in connection with fractures of the lower extremity of the radius.

The **metacarpal** bones are often broken, either by direct violence or indirectly, by force applied at the knuckles, as in striking a blow with the closed fist. The **phalanges** are often involved in crushing injuries, and are often the subject of simple fracture from direct violence.

In the *treatment* of fractures of the bones of the *hand*, immobilization upon a palmar splint is indicated. The splint should extend halfway up the forearm above, and beyond the tips of the fingers below. It should be padded so as to fit the normal inequalities of the palmar surface of the hand and afford even support to the injured bone. In dealing with the frequent compound and crushing injuries of the hand, no fragment of bone that is not wholly separated from its vascular connections should be removed, but all fragments should be adjusted as well as possible, and so supported as to secure consolidation with the minimum of deformity, leaving to a later period the removal of parts that time and use may show to be useless and unsightly.

The Pelvis.—Fracture of the bones of the pelvis, at any point in their extent, may result from direct violence. Disruption of a pelvic articulation, with irregular tearing away of some part of the adjacent bony substance, is relatively frequent. Any of the various processes of the innominate bones may be broken without fracture of the pelvic girdle proper. The iliac wings, by reason of their prominence, are most exposed to fracturing violence.

The pubic bone is the part of the true pelvic girdle most frequently broken. Thus, out of 18 cases of pelvic fracture received at the Methodist Episcopal Hospital, New York, within nine years, in 6 the fracture was confined to the iliac wings, in 4 there were extensive multiple fractures, in 1 there was a diastasis of the symphysis pubis, in 1 both pubis and ilium were involved in the fracture, in 3 the pubic bone or bones only were broken, in 1 there was a fracture of the ilium and ischium with diastasis of a sacro-iliac articulation, and in 2 the injury seemed to be a sacro-iliac diastasis only.

The nature of the violence sustained in these cases illustrates well the character of the more common causes of fracture of the pelvic bones. In 6 instances it was a railroad crush, in 4 a fall from a height, and in 1 each a crush under a bank of earth, a crush in an elevator shaft, and a crush from the wheel of a wagon passing over the pelvis.

It is seldom that the fragments become much displaced, so that perceptible deformity is rarely present; but unnatural mobility and crepitus can usually be elicited by manipulation, to which are added local tenderness and wide-spreading ecchymosis as symptoms to establish the diagnosis.

The importance of fractures of the pelvic bones attaches not so much to the injury to the bones themselves as to possible coincident injury of the pelvic viscera or blood-vessels, or to the existence of other serious injuries in other parts of the body. The urinary bladder and the urethra are especially liable to be injured, and an investigation of their condition should be among the first attentions rendered in a case of pelvic injury. Contusion of some portion of bowel or of the

kidney is a frequent complication; and laceration of an iliac vein or one of its main branches may occasion fatal internal bleeding.

The *acetabulum* may be the seat of a fracture limited to its own area by the impact of the head of the femur. Instances are reported in literature in which, as the result of a fall upon the great trochanter, the head of the femur has perforated the dome of the acetabulum, even to full penetration into the pelvic cavity. Such an accident is not easily distinguishable from fracture of the neck of the femur, except in case of actual intrapelvic penetration, when a rectal exploration of the internal lateral wall of the pelvis will reveal the presence of the intruding head of the femur.

The *rim of the acetabulum* may be chipped off, to a greater or less extent, as a complication of a dislocation of the head of the femur, when, in the production of the displacement, the head of the bone has been driven with great force against the containing rim of the joint-cavity. Such an accident would add to the symptoms of dislocation that of crepitus indicative of the fracture, together with a tendency to redislocation after reduction. The character of the violence required for its production is so extreme that other and more important, usually fatal, injuries are likely to complicate the case, so that, in fact, the injury to the rim of the acetabulum has but little more than a pathological interest.

The coccyx may be fractured by falls, kicks, or the violent impact of a fetal head escaping through a narrow inferior strait. Union at an angle is likely to result.

As regards the **after-course** of pelvic fractures in general, special interest attaches only to complicating injuries. The little tendency to displacement of the fragments and the vascular nature of the bones ensures early repair with firm union.

In the **treatment** of fracture of any portion of the pelvic girdle proper, it is required, in addition to the dorsal recumbent position, that the pelvis be surrounded by a broad, snugly drawn bandage. This support should be maintained for four weeks or more. In fractures limited to an iliac wing, such pelvic bandage should be omitted, owing to its tendency to displace the fragment.

The Femur.—Fracture of the femur is of comparatively frequent occurrence, forming about 6 per cent. of all fractures. The neck and the middle third of the shaft are most frequently broken. Such special conditions attach to the injuries of each of the extremities and of the shaft as to necessitate separate consideration of each of those regions.

The upper extremity includes the head, neck, and trochanters. It may be broken at any part of its extent, the most frequent cause being a fall upon the outer side of the hip. Such fracture may occur at any age, but is by far the most frequent in old people, in whom the strength of the femoral neck is often lessened by senile osteoporosis. This degeneration of the cervical substance occasionally becomes so great that fracture of it results from very trivial violence, such as a sudden twist of the body, a trip, a misstep, or other slight force applied vertically by impact upon the foot or knee. Fracture thus caused is at the weakest part of the neck, its most constricted part, immediately behind the head and within the capsule. In adolescents, the tearing away of the upper epiphysis alone is conceivable as a possibility from extreme violence. In one recorded case, the existence of the injury was confirmed by autopsy.

In fractures produced by a direct blow upon the great trochanter—that is to say, in the vast majority of fractures of the upper extremity of the femur—there is always at first more or less impaction of the

FIG. 265.—Impacted fracture at the base of the neck of the femur. Union with exuberant ossified callus.

fragments. When the line of fracture is through the neck and chiefly within the capsule, the lower and posterior wall of the distal fragment, as a rule, is driven into the spongy tissue of the head, which is driven downward and inclined backward. When the fracture is at the base of the neck, its line falling mostly, if not entirely, outside the capsule, the acetabular fragment is driven into the trochanteric portion, as shown in Fig. 265. Again, impaction is deepest behind and below, causing the trochanter major to be turned backward and the whole limb to be everted. Widely varying degrees of impaction and comminution will be present in different cases, depending upon the violence of the force and fragility of the bone. The trochanter may be penetrated with such force as to be split into several fragments, as shown in the specimen illustrated in Fig. 266. On the other hand, the fracture may be incomplete—a condition more likely to be met with in young subjects. The periosteum investing this portion of the femur is so thickened and strengthened by fibers reflected from the capsule and the tendons inserted into the trochanter, that it is seldom completely torn

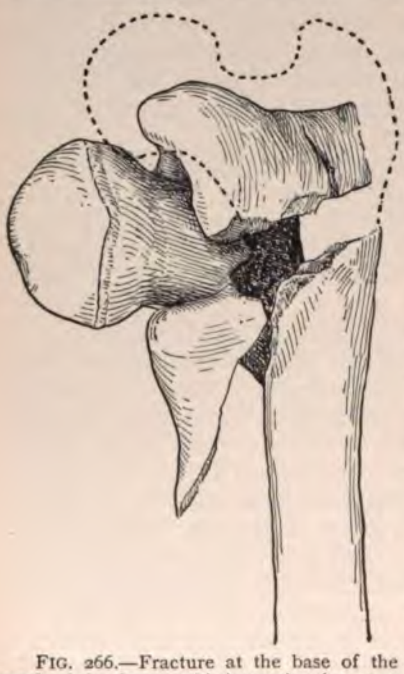

FIG. 266.—Fracture at the base of the neck of the femur, with impaction into trochanteric expansion, comminution, and wide separation of fragments (Museum of the M. E. Hospital, New York).

through when the bone is fractured. The untorn portion serves to hold the fragments together, and may be an important source of vascular supply to the proximal fragment when the line of fracture is through the narrow part of the neck. Later, it may be torn completely through by too energetic diagnostic manipulations of the bone or by too early attempts at walking, or it may become gradually elongated by muscular traction while softened by inflammatory changes.

The normal softening of the bony tissue immediately adjacent to the line of fracture, which is the first stage of repair in all bones, is prone to become exaggerated in fractures through the narrow part of the neck, owing to the antecedent osteoporotic degeneration and to the limited supply of blood to the acetabular fragment. Gradual absorption of the softened tissue is prone to occur, and in some instances the entire neck disappears. An extreme degree of this disappearance of the neck is shown in Fig. 267. When the fracture is at the base of the neck, however, the conditions for repair are reversed, and often there is an exuberance of new-bone production.

FIG. 267.—Fracture of the neck of the femur; non-union, absorption of the neck, fragments loosely connected by the capsule.

Of the *symptoms* attending fracture of the neck of the femur, the immediate helplessness of the limb which follows the injury is in the great majority of cases very marked, although in exceptional and rare instances the ability to walk has not been absolutely lost. Much pain is usually complained of, especially upon any attempt at rotation or flexion at the hip; an unnatural fulness may generally be noted anteriorly in the fold of the groin, and pressure made in this region in the direction of the neck is painful. Outward rotation of the whole limb, evidenced by eversion of the foot, is the rule. To this eversion contribute the greater interpenetration of the tissues of the posterior wall of the broken neck, the strong contraction of the irritated external rotator muscles, and the natural weight of the limb. Inversion of the foot has, however, been reported to have been present in some authenticated cases, so that the absence of eversion does not absolutely negative the existence of a fracture through the neck of the femur. The amount of shortening immediately following the injury will vary according to the degree of impaction, or, in the absence of impaction, to the amount of laceration of the capsule and the periosteo-aponeurotic investment of the neck and the consequent longitudinal displacement from muscular contraction. A slight primary shortening due to impaction may gradually become much greater through the interstitial absorption of the neck, and, in the absence of impaction, later increase of shortening may imperceptibly develop from the consecutive stretching of the fibrous bands which connect the fragments. Often at first there is no appreciable shortening, or, if any is present, it is limited to a fraction of an inch. After some weeks or months, a shortening of 2

inches or more may be found to be present. The position and prominence of the great trochanter will be influenced by the degree of impaction, shortening, and eversion; being less prominent and lying above its natural position, according as the axis of the neck is shortened and depressed. When it has been split and its fragments separated by the wedge-like action of the neck driven into it, the massive callus which invests it can often be plainly felt by palpation. Crepitus is seldom easily elicited; usually it is prevented by the existing impaction, and, in the absence of impaction, is still interfered with by the mobility of the acetabular fragment.

The *diagnosis* of fracture of the neck of the femur is usually attended with little difficulty or uncertainty. The assemblage of symptoms is characteristic; a history of a fall upon the hip, or of disability suddenly induced in an aged person by a slight strain or concussion confirms the diagnosis. Severe contusion without fracture may cause symptoms which at first closely simulate those due to fracture. In case of doubt, the more serious condition should be considered as present, until the rapid subsidence of tenderness and helplessness has demonstrated the real nature of the accident. Much uncertainty will frequently exist as to the exact point along the neck at which the fracture has occurred, and especially as to the relations of the line of fracture to the insertion of the capsule. As this point is of importance only in the prognosis of the case, no extended and violent manipulations for the purpose of determining it are justifiable, in view of the possibility of thereby breaking up impaction or lacerating periosteal and capsular bands that may still connect the fragments. No manipulations that cannot readily be born by the patient without an anesthetic should ever be made, and even these should be made with particular care and gentleness.

In the case of young children, the symptoms caused by fracture of the neck of the femur may possibly be mistaken for those of coxitis, especially since the fracture is likely to be an incomplete one, attended with bending of the neck without actual separation of the fragments, and the ability to walk with a limp is regained in a short time; besides, the possibility of fracture of the neck of the femur in young children is not generally recognized. The immediate supervention of the characteristic symptoms of helplessness, pain, muscular spasm, deformity, and eversion of the limb after an injury to the hip in the case of a child should be sufficient to differentiate it from the slow and irregular onset of tuberculous coxitis.

The *prognosis* will be affected by the age of the patient, the proximity of the seat of the fracture to the head of the bone, and the presence or absence of impaction. Some permanent impairment of the functions of the limb is in all cases to be expected, even in those that pursue the most favorable course. This may vary from a slight limp to total helplessness of the limb. Death within a few days is not uncommon in aged persons, from the effects of the shock and the local inflammatory reaction; death frequently follows, also, after some weeks or months from renal and pulmonary complications, induced or aggravated by the confinement or suffering incident to the injury, from exhaustion due to decubitus, or from the supervention of suppuration about the fracture. Non-union, usually without any intervening material connecting the two fragments, sometimes with strong fibrous adhesions, is the usual result of fractures through the narrow part of the neck. To this contributes not only the absorption of the neck, noted in a previous paragraph, but also the impossibility in many cases of securing accurate coaptation and

prolonged immobilization of the fragments, owing to the serious effect upon the general condition of the patient produced by the confinement required, which often early compels the total abandonment of all efforts at retention and immobilization. The possibility of bony union occurring after a fracture of that part of the neck within the capsule has been denied by many. That it is very rare is certain; but it is reasonable to grant that, in exceptional cases, a firm impaction of the fragments and the presence of a broad strip of untorn periosteum may secure sufficient fixation and nutrition to the acetabular fragment to ensure bony union ultimately. The repair will be slow, and may be arrested by too early attempts at use of the limb. The use of retentive apparatus should be persevered in for a period of not less than ninety days, whenever there is any reason to hope for bony union. Fractures at the base of the neck unite by bony union, if apposition and immobilization are maintained. The certainty and rapidity of their repair are frequently favored, and their treatment is often greatly facilitated, by the presence of deep and firm impaction. The possibility of consecutive shortening from absorption of the neck has been described in a previous paragraph. In children, a gradual increase of shortening and deformity during adolescence, from further descent of the depressed neck, may be expected.

Treatment.—In all cases, efforts to bring the fragments into apposition and to immobilize them should be at once inaugurated.

The existence of impaction is of the utmost importance in facilitating treatment, and every effort should be made during the preliminary care and examinations to preserve it when present, the patient being placed upon a firm hair-mattress. Lateral pressure and support should be given to the injured hip by a stout pelvic bandage drawn snugly; this may be reinforced by a sand-bag applied under the trochanter so as to support it and prevent further tendency to eversion; the foot should be protected from the weight of the bed-clothing by a suitable cage. Additional fixation may best be secured by moulding to the posterior aspect of the limb and body a bar of soft iron, $\frac{3}{8}$ inch in thickness and $1\frac{1}{2}$ inches wide, long enough to reach from the axilla to the lower fourth of the leg. To this should be united a transverse band of lighter material at each end, the upper one long enough nearly to embrace the thorax, the lower one the ankle. A third transverse band is added at a point so that it shall embrace the thigh just below the perineal crease. This apparatus is secured in place by proper bandaging, as shown in Fig. 268. This will be recognized as the splint devised by Thomas for the treatment of hip-joint affections. Various modifications of it may be required to suit it to the peculiarities of individual cases. Weight extension may be added, if necessary to control tendency to shortening. This apparatus secures fixation quite satisfactorily, while it greatly

FIG. 268.—The Thomas hip-splint.

facilitates the nursing required by the patient. After it has been applied, the patient may be lifted or turned upon the sound side, and, still wearing the splint, may be got out of bed upon crutches some weeks earlier than would otherwise be prudent. The splint may be discarded entirely at the end of from twelve to sixteen weeks.

Another method is to apply a long wooden side-splint extending from ankle to axilla, with or without extension, according to the tendency to shortening.

Whenever there appear evidences of serious impairment of health, due to attempts at immobilization, they must be abandoned, and the general condition of the patient attended to.

The shaft of the femur may present any variety of fracture to which a long bone is liable, whether from direct or indirect violence or from the contraction of its own muscles. The line of fracture is usually oblique, as shown in Fig. 269; but transverse fracture is not uncommon, especially in children, in whom also the preservation untorn of a part of the periosteal investment of the fractured region is frequent. Notable displacement, longitudinal, angular, and rotary, usually attends fracture of the shaft. This is due both to the primary fracturing force and to the subsequent action of the powerful muscles of the thigh.

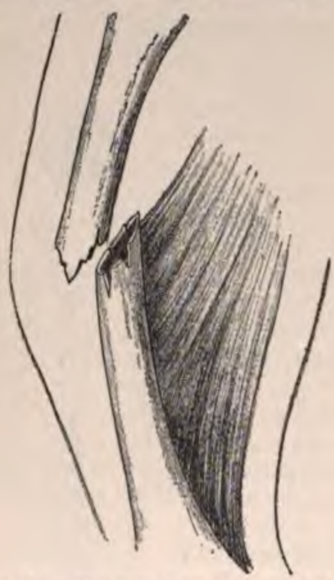

FIG. 269.—Common form of fracture of the shaft of the femur (Hoffa).

FIG. 270.—Diagram illustrating direction of chief lines of muscular contraction, with tendency to displacement resulting after fracture of upper third of the femur.

This tendency to displacement assumes especial importance from its bearing on the progress of repair and upon the possibilities of permanent deformity and lameness. Obliquity of the fracture, generally present, favors the slipping of the fragments by each other, the tendency to which is inevitable, from contraction of the parallel muscular masses which invest the bone. The lower fragment is usually drawn to the

inner side and behind the upper, with the formation of a more or less well-marked angular deformity, the projection of which is often visible on the anterior and outer aspect of the thigh. The tendency to this angular deformity is more apt to be great in fractures of the upper third of the shaft, in which, in addition to the action of the peroneotibiopelvic muscles upon the lower fragment, the upper fragment is prone to be tilted upward by the action of the iliotrochanteric muscles (Fig. 270). The effect of muscular contraction may, however, be much limited by the strength of the tendinous and aponeurotic investments remaining untorn about the seat of the fracture.

Tendencies to outward rotary displacement of the upper fragment from the uncontrolled action of the external rotators inserted into the great trochanter, and of the lower fragment from the natural tendency from gravity of the foot to fall upon its outer side, also characterize these injuries.

The *diagnosis* of fracture of the shaft of the femur is usually without question upon simple inspection and manipulation of the limb, by which the classical signs of fracture are at once appreciated. The thickness of the overlying soft tissues, however, prevents, in most cases, the accurate recognition of the details of the line of fracture and of the displacement. More exact knowledge may be obtained by the freer manipulation which general anesthesia would make possible; but the use of such extended manipulations should rarely be resorted to, on account of the increased damage to the surrounding soft tissues, which they produce. An *X*-ray skiagraph, when procurable, is of especial value in demonstrating the exact relation of the fragments. Comparative measurement of the length of the two limbs is of great value for ascertaining the longitudinal displacement. It should be frequently done during the first weeks of treatment, for the purpose of controlling the extending force to be used. When measurements are taken, it is important, in order to render them exact for purposes of comparison, that the patient should lie upon a flat, firm surface, that the pelvis should not be tilted in any direction, and that the longitudinal axis of each limb should make the same angle with the transverse axis of the pelvis.

One end of the measuring tape should then be firmly pressed against the lower surface of the projecting anterior spine of the ilium above, while the lower end is carried to the lower edge of the internal malleolus at the ankle. Great care and repeated comparison of measurements are required to avoid errors due to the readiness with which the soft tissues covering the prominences named glide under pressure.

Prognosis.—This injury is always a serious accident, requiring, under usual methods of treatment, confinement to bed for weeks, entailing considerable disability and lameness for months, and, in some cases, such shortening as to cause permanently a limping gait. Usually, in adults, a simple fracture of the shaft of the femur, intelligently treated, will by the end of eight weeks consolidate with sufficient firmness to make it prudent for the patient to be allowed out of bed on crutches, which after four weeks more may be discarded altogether. While the possibility of union in especially favorable cases (such as transverse fractures and fractures in children, without shortening) is undeniable,

still, no special method of treatment can be depended on to ensure it in any given case. The normal asymmetry of the two limbs is not to be overlooked in estimating the results of treatment, for a normally longer limb will possibly still be as long as the opposite one, notwithstanding considerable shortening; or, on the contrary, a normally shorter limb may, after consolidation, present apparently marked shortening, when the amount of shortening due to the injury has actually been slight. Exact apposition of the fractured surfaces can rarely be secured, nor can some overriding of the fragments be prevented, however intelligent and assiduous the care. A result is to be accepted as good when bony

FIG. 271.—Fracture at the middle of the shaft of the femur. Union with shortening and external angular deformity (Warren Museum, Boston).

union has been secured with no perceptible angular deformity, when the normal outward inclination of the foot has been preserved, and when the shortening of the limb does not exceed an inch. In the majority of cases, this should not be more than ½ inch in amount. The lapse of some time—at least one year—is necessary before final judgment can be formed as to the perfection of functional recovery.

Treatment.—The recumbent position, with some form of continuous extension, combined with apparatus for the immobilization of the fragments, is requisite. A proper bed is important. It should be narrow, preferably 36 inches in width. The mattress should be of hair, firmly made, not more than 4 inches thick, and should be placed upon an even, unyielding surface, best and most conveniently secured by placing underneath the mattress, between it and the springs which usually support it, a layer, an inch thick, of matched boards, like those of a door. Thus the nates are prevented from sinking down into the mattress, and the necessary care for the reception and removal of excretions is facilitated. Decubitus is to be prevented by the use of pillows and pads, as required to shift pressure and promote comfort. Holes in the mattress or special apparatus for raising the patient are rarely, if ever, necessary. Sufficient access to the urethra and the rectum can be had by raising the sound thigh.

Extension is best secured by the continuous traction of a weight (a bag of shot or sand, etc.) fastened to a cord which, passing over a pulley attached to the foot of the bedstead, is fastened to strips of adhesive plaster which have been applied to either side of the injured limb from the ankle up to the point of fracture. Fig. 272 shows the method of applying these strips. They should extend upward above

the knee, along the thigh to a point a little above the level of the fracture. The complete apparatus is shown in Fig. 274. For the purpose of lessening the resistance to extension caused by the burrowing of the foot and leg into the mattress, they should be lifted from the surface of the mattress and supported upon the sliding apparatus shown in Fig. 273 (Volkmann's sliding rest) and also in Fig. 274.

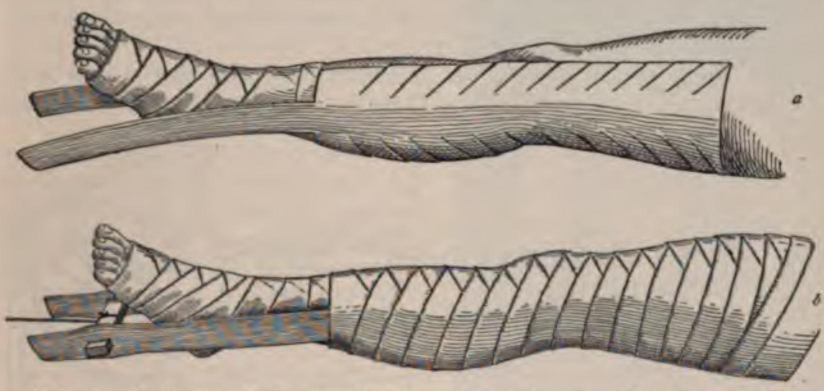

FIG. 272.—Application of adhesive strips for making continuous weight-extension of leg and thigh: *a*, the adhesive plaster shaped and applied; *b*, the retaining roller bandage applied, and the apparatus ready for attachment of the weight.

Sufficient counterextension is obtained from the weight of the body, aided by elevating the foot of the mattress-board, or of the bedstead if preferred, to the extent of 6 or more inches. This extension apparatus should be applied as soon after the accident as possible. By the continuous tension of a moderate weight-traction thus exerted, the inevitable spasm of the thigh muscles is gradually overcome, and the overriding of the fragments is corrected. A weight of 10 pounds

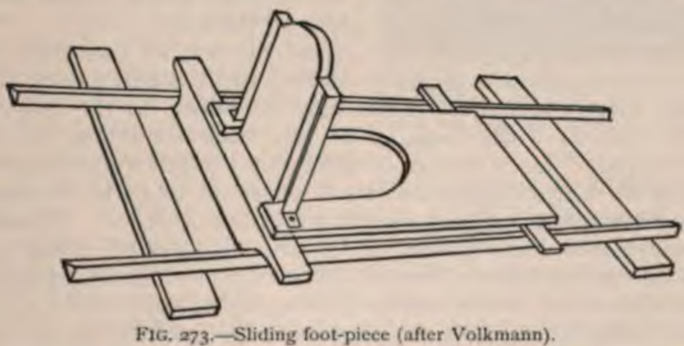

FIG. 273.—Sliding foot-piece (after Volkmann).

should be attached at first in the case of an adult, this being increased from day to day, as found necessary, until measurements show the injured limb to be of equal length with its fellow. About the fifth week the weight may be discarded. At the same time the whole limb should be steadied by a posterior splint reaching from the gluteal crease above to the lower edge of the calf below. Liberal padding

should be placed under the knee, so as to flex it slightly, and thus prevent the painful hyperextension of the knee-ligaments otherwise caused by the weight-traction. The roller bandage by which this posterior splint is fixed to the limb, applied with moderate firmness below the knee, should be sufficiently loose along the thigh to accommodate later swelling. For the immobilization of the fracture chief reliance is to be placed upon a long external splint reaching from the axilla above to beyond the sole of the foot below. The application of this splint is shown in Fig. 274.

The lower end of this splint passes through the slot shown in the footpiece of the sliding rest, and thereby full control of any tendency

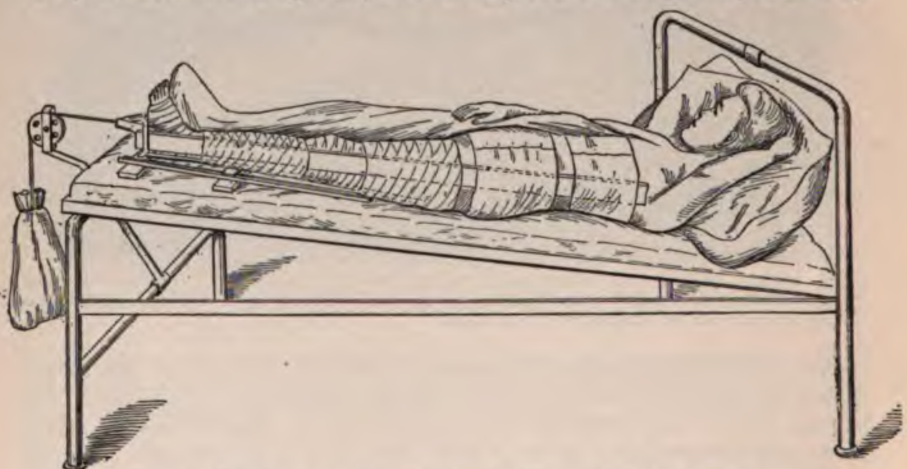

FIG. 274.—Complete permanent dressing for fracture of shaft of the femur.

to outward rotation of the foot is secured, for by tilting the transverse pieces which support the tramway along which this foot-rest slides, any lateral inclination desired can be given to the foot.

At the expiration of a week, the tendency to shortening having been overcome, and the primary swelling of the thigh having begun to subside, short coaptation splints may be added to the internal and anterior surfaces of the thigh. The retention of the limb in its splints will be required for a period of from eight to ten weeks before sufficiently firm consolidation will have occurred to make it prudent to dispense with them and get the patient up on crutches. Should, however, any reason arise making it important to get the patient out of bed at an earlier date, or should delay in consolidation indicate need for the stimulus of locomotion and the upright position, and relief from tedious confinement, sufficient support to the fracture may be obtained by encasing the limb and pelvis in plaster-of-Paris bandage, or by the application of the iron hip-splint of Thomas (Fig. 275), or some form of the traction-braces used in the treatment of hip disease. In children, on account of their restlessness and the special attentions needed to keep the dressings free from urine and feces, vertical suspension of the limb (Fig. 276) may with advantage be substituted for the longitudinal extension used for older patients.

In some cases of **fracture through the upper third of the shaft,** the tendency to displacement may be so great that it cannot be overcome until the thigh-muscles are relaxed by moderate flexion of the thigh upon the pelvis and of the leg upon the thigh. This can be accomplished by placing the limb upon a double inclined plane (Fig. 277). Traction in the long axis of the femur may be obtained by applying the adhesive straps to the thigh only, and elevating the pulley at the foot of the bed.

FIG. 275.—Thomas's hip-splint used as an ambulatory appliance in a case of fracture of the shaft of the femur with delayed union.

The **lower third of the femur** may be broken by direct violence, or by such indirect force as a fall upon the feet or knee, or a propulsion forward of the body with the knee held in hyperextension, or by a combination of torsion and traction. Fractures in this portion of the bone have an especial gravity on account of the proximity of the knee-joint, the possibility of the popliteal blood-vessels being compressed or lacerated, and the tendency to excessive blood-extravasation from the torn vessels of the vascular bone and the investing periosteum.

The line of fracture may be more or less transverse from side to side, with anteroposterior obliquity, or may run obliquely, detaching a condyle and entering into the knee-joint. There may be much comminution, with or without impaction of fragments. In childhood and youth, the lower epiphysis alone may be torn away—an accident which, in the majority of reported cases, has been caused by entanglement of the leg in a revolving wheel. The displacement depends chiefly upon the direction of the fracturing force and the lines of obliquity presented by the fragments. In supracondyloid fractures, the line of fracture is often oblique, from behind downward and forward, with protrusion of the lower end of the upper fragment forward and downward toward the patella (Fig. 278); but displacement of an opposite character is not infrequent. When with the first-mentioned displacement the line of fracture is above the insertion of the gastrocnemii muscles, the lower fragment may, in exceptional instances, become so strongly flexed by the contraction of these muscles that the fractured surface projects backward into the popliteal space, and great, sometimes insuperable, difficulties may attend efforts to secure proper

adjustment of the fragments. In epiphyseal separations, the line of fracture is just below the origin of this calf-muscle, and in the majority of reported cases the epiphysis has been dislocated forward, retaining its normal relations to the knee-joint and the tibia, while the lower end

FIG. 276.—Method of applying vertical suspension of the limb in the treatment of fracture of the femur in a child.

of the diaphysis has projected backward and downward into the popliteal space (see Fig. 279).

Contraction of the gastrocnemius, attached to this fragment, intensifies the displacement and resists attempts at reduction. In a number

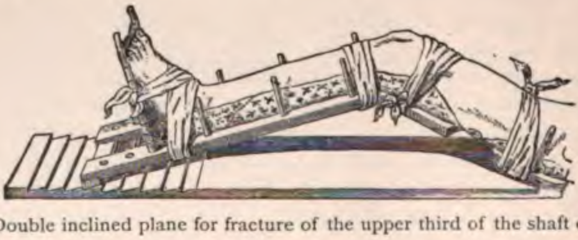

FIG. 277.—Double inclined plane for fracture of the upper third of the shaft of the femur.

of reported cases the popliteal vessels have been lacerated by the sharp edge of the displaced fragment, or have been so compressed by it as to produce gangrene of the parts distal to it. In the treatment, accurate reduction, under general anesthesia, is of primary importance. Relaxa-

tion of muscles by flexion of the leg upon the thigh and of the pelvis should be first secured. While the parts are kept in this position, the reduction is to be effected by manipulation and extension. In many instances retention of the fragments in position after reduction may best be maintained by keeping the leg flexed for a time upon the thigh, at an angle as acute as can be borne with comfort by the patient, the fixation being effected by suitable bandaging, while the limb as a whole is supported upon pillows or is slung in a hammock.

Any tendency to shortening is prevented by the breadth of the fractured surfaces and the interlocking of their irregularities after reduction

FIG. 278.—Fracture through the lower third of the femur healed in deformity; displacement of the lower end of the upper fragment downward and forward (Holthouse).

FIG. 279.—Diagram showing usual displacement after separation of the lower epiphysis of the femur (Robson).

has been effected; while muscular contraction is largely antagonized by the position. In exceptional cases it may be well to put the calf-muscles still further at rest by section of the tendo Achillis. Plaster-of-Paris bandages may be used to advantage in some instances. By the third week, the angle of flexion may be reduced a half, and soon thereafter a straight position will be possible, without disturbing the apposition of the fragments. In many cases, after reduction, the straight position, with or without weight-extension, as the presence or absence of tendency to shortening may indicate, may be employed from the first. Wound of either of the great popliteal vessels calls for exposure of the injured point by free incision and ligation, with either amputation at once or its postponement until the possible failure of conservative measures shall have unmistakably declared its necessity. If the knee-joint has been penetrated, either by the primary line of fracture or by

a sharp spicule of the displaced upper fragment, it may become greatly swollen by blood-extravasation. If absolute asepsis is obtainable, this may be evacuated by aspiration or incision; otherwise, its removal must be left to absorption, aided by massage and bandage-compression.

FIG. 280.—Transverse fracture of the patella.

FIG. 281.—Comminuted fracture of the patella.

FIG. 282.—Vertical fracture of the patella.

Long-continued stiffness of the joint and, in some cases, permanent ankylosis remain, whatever the treatment.

The Patella.—Fracture of the patella is usually the result of cross-breaking strain exerted upon the bone by the contraction of the quadriceps femoris, when in flexion of the knee the patella is only partially supported by the convexity of the condyles. Often direct violence combines with muscular action to effect the fracture, as in a fall or blow

FIG. 283.—Fracture of the patella, showing defective apposition of fracture-surfaces even where fragments are brought into contact by manipulation through overlying soft parts (Warren).

upon the bent knee. In very exceptional instances, fracture is caused by direct violence alone.

The line of fracture, as a rule, is transverse or slightly oblique, being

seated at or just below the middle of the bone. Stellate or vertical lines of fracture occur as the result of direct violence (Figs. 280–282). The overlying fibrous coverings of the bone are stretched and irregularly torn, and the tear extends laterally to a varying degree, in different cases, into the aponeurotic capsule of the knee-joint. The degree to which the upper fragment is retracted depends upon the extent of laceration of these fibrous investments; usually the separation does not exceed an inch in extent, but occasionally it amounts to 3 or more inches. In fracture by direct violence alone, the fibrous investments may be but slightly torn, and no appreciable separation of the fragments may result (Fig. 283). Tilting of the fragments, so that their fractured surfaces no longer face each other, is frequent (Fig. 283). The fractured surface of the upper fragment is prone to be turned in toward the cavity of the knee-joint by the action of the vasti fibers

FIG. 284.—Transverse fracture of the patella; fractured surface partially covered by irregular flaps of torn aponeurosis (Hoffa).

FIG. 285.—Fibrous band of union after fracture of the patella (Hoffa).

inserted into its sides, while the distal fragment may be tilted forward by fluid effused into the joint.

Into the gap between the fragments the prepatellar tissues fall, and a fringe or apron, composed of shreds of the stretched, lacerated, fibrous covering of the patella, in many cases invests much of the fractured surface, more especially of the proximal fragment (Fig. 284). The defective apposition of the fractured surfaces and the presence between the fragments of so much fibrous tissue is sufficient, as a rule, to prevent bony union effectually, however carefully the part is immobilized and retraction of the upper fragment prevented. As exceptions to this rule stand only some fractures by direct force in which neither extensive laceration of the fibrous investments nor much separation of the fragments has occurred.

The fibrous band uniting the fragments (Fig. 285) does not exceed $\frac{1}{2}$ inch in length in most favorable cases, and the functions of the limb may not be noticeably impaired. Gradual elongation of the uniting medium is, however, of frequent occurrence, so that the distance between the fragments, which upon the removal of apparatus was scarcely $\frac{1}{2}$ inch, may be found after some months to have become several inches. Complete rupture of the band has been frequently recorded.

Wide separation of the fragments is not incompatible with usefulness of the limb, whenever that portion of the aponeurosis of the vasti muscles which is inserted into the sides of the lower fragment has remained intact. Marked rigidity of the knee-joint persists, as a rule, for some time after the removal of apparatus, due to the peri-articular contractures and adhesions following the inflammatory and hemorrhagic infiltrations of the soft tissues and the long disuse of the joint. This gradually diminishes under ordinary use, but in most cases some diminution of range of flexion and loss of power of active extension persist throughout life. Occasionally the knee remains quite stiff.

The **symptoms** of fracture of the patella are at once recognizable by sight and touch; the division of the bone into fragments more or less widely separated and capable of individual mobility declares unmistakably the nature of the accident. The loss of power is usually, but not necessarily, at once complete; it is dependent in some measure upon the extent of the laceration of the lateral aponeuroses. Distention of the knee-joint supervenes rapidly from the accumulation of blood and serum within its cavity, and extensive ecchymosis of the adjacent connective tissue quickly follows.

Treatment.—The knee-joint should be immobilized by a suitable splint adjusted to the back of the limb, while the foot is elevated upon a pillow (Fig. 286). An ice-bag or an evaporating lotion should be applied to the knee to check effusion and limit inflammatory reaction.

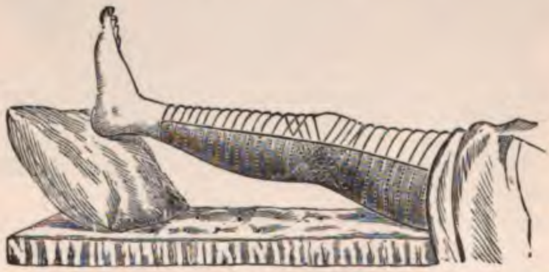

FIG. 286.—Showing back splint and elevation of foot advised for fractured patella (Hamilton).

After the third day these may be omitted, and the absorption of effusion promoted by the elastic pressure of a flannel roller bandage, aided by massage. Retraction of the upper fragment is to be controlled by adjusting a shield of adhesive plaster to the front of the thigh, so that the lower edge of the plaster, when drawn upon, shall encompass the upper edge of the patella. To the lower lateral angles

of this shield strong elastic bands are fastened, which are attached below to the under surface of the splint at the ankle, and, drawn tense, may exert a constant downward pressure upon the fragment. The subsidence of the swelling and the tendency of the superficial tissues to glide make frequent readjustment of this apparatus necessary.

The permanent splint to be worn during immobilization is best made from several layers of canton flannel or towelling saturated with plaster-of-Paris cream, secured while still plastic to the posterior aspect of the limb by a roller bandage. The pieces of cloth should be long enough to reach from the ankle to the gluteal crease, and wide enough to cover two-thirds of the circumference of the limb; at the joint the splint should not extend above the most projecting point of the condyles. Two thicknesses of the cloth suffice for the greater portion of the splint, but these should be reinforced in the middle under the knee by two extra layers. The adjustment of this permanent splint should be deferred until the primary joint-swelling has subsided. The posterior immobilizing splint should be retained for six to eight weeks, but after the first week daily massage of the quadriceps femoris muscle should be made, access to the anterior portion of the thigh requiring merely the temporary removal of the outer bandage. After the third week the whole apparatus should be daily removed, and massage of the joint, with gentle passive movements, added. By this method of treatment a close, strong, fibrous bond may be secured with the least amount of joint-disability.

Failure to secure bony union is due to the presence of fibrous tissue between the fragments, and no prolongation of the period of immobilization, nor special method of approximation will secure other than fibrous union, unless this is removed. To accomplish this would require free exposure of the fracture-surfaces by incision through the overlying soft parts, but the risks of subsequent suppuration within the knee-joint are too great to render such incision advisable, except by a surgeon skilled in aseptic operative technic. When, however, the necessary aseptic conditions can be secured, the fracture should be exposed by a free longitudinal incision, the shreds of fibrous tissue and the blood-clots which cling to the broken edges should be removed, the blood within the joint-cavity should be gently sponged or irrigated out, and the fragments should be secured in close apposition by sutures passed through the overlying periosteum, and through the aponeurosis on either side. Chromicized catgut is preferable for these sutures. The insertion of silver wire through the bony substance of the fragments to hold them together is unnecessary and objectionable, on account of the amount of handling and bruising of the parts which it entails. The superficial incision should then be closed by two tiers of sutures, one, of catgut, to the deep fascia, and one, subcuticular, of silk or fine silver thread. The posterior plaster splint should then be applied. After four weeks this splint should be left off, passive movements instituted, and attempts at walking begun. By the end of the sixth week all restraint of the active use of the limb may be abandoned, and free flexion encouraged. Cases thus treated show uniformly rapid, firm, bony union, with a minimum amount of peri-articular stiffness and muscular atrophy. The risks of infective accident are, however, too

great to render this method of treatment advisable for adoption by the general practitioner in recent simple fracture. In cases of compound fracture, however, it should be done as a matter of routine, with special precautions as to the thorough cleansing and drainage of the joint. In old cases of fracture, with noticeable disability from non-union, exposure by incision, removal of intervening soft tissue, refreshing of the bone-edges, approximation and suture together of the fragments, should be done, if safeguards of asepsis can be assured. Owing to the tension required in most of such old cases to bring the fragments into apposition, wiring of the fragments together is usually called for in this class of cases.

Numerous methods have been suggested for tying the fragments together, in recent cases, by thread passed under or around them subcutaneously, without a free incision into the injured area. All these methods, however, fail to meet the prime indications for removing the fibrous material that may be between the fragments and of clearing the joint of blood-clots, while they entail risks of infection nearly as great as those which attend open incision. The use of steel hooks whose points, penetrating the skin until they become engaged in the anterior surface of the fragments, can be approximated, and thus draw and hold together the fragments, has only historical interest.

FIG. 287.—Comminuted fracture of the bones of the leg. Machinery accident; bone-injuries attended by extensive laceration of soft tissues, necessitating amputation above the knee.

The Leg.—Fractures of the bones of the leg are second in the order of frequency only to those of the bones of the forearm. In by far the largest proportion of cases, both the tibia and the fibula are broken. The tibia and the fibula are alone broken in about equal degrees of frequency. The lower third of these bones is the most frequent seat of fracture, but fractures involving the middle or upper thirds are not infrequent. All the varieties of fracture and all the causes of fracture met with in fractures of other long bones find their counterpart in the bones of the leg. In this region compound fracture is met with more frequently than in any other part of the body, owing to the subcutaneous position of the tibia and the frequency with which a direct blow or crushing violence is sustained by the legs.

Fracture involving the upper third of the bones of the leg presents special conditions the nearer it approaches to the knee-joint.

Impaction of the lower fragment into the upper, with comminution of the upper fragment, the lines of fracture opening into the knee-joint, may result from falls upon the feet from a height. Free hemorrhage into the cavity of the joint and the involvement of the peri-articular structures in the inflammatory conditions provoked by the fracture are

unavoidable. Prolonged joint-stiffness and swelling are the result, and permanent impairment of function is possible. Owing to the proximity of large blood-vessels and important nerve-trunks, additional complications due to their laceration or compression occasionally arise. Isolated fracture of the upper end of the fibula, which may occur from direct violence or from the pull of the biceps muscle under certain conditions, is especially liable to have associated with it rupture or contusion of the peroneal nerve, and consequent paralysis of the structures supplied by it. Instances of separation of the upper epiphysis of the tibia are recorded, in some of which there has resulted premature ossi-

FIG. 288.—Fracture of the shaft of the tibia and of the fibula, with external rotary displacement (Hoffa).

FIG. 289.—Comminuted fracture of the tibia; leg run over by the wheel of a street-car.

fication of the interepiphyseal cartilage and arrest of so much of the growth of the bone in length as depends upon that structure.

The displacement attending fractures of the leg near the knee is usually merely that resulting directly from the fracturing force, and, when once overcome by manipulation, does not tend to recur; but in some instances the contraction of the hamstring muscles is sufficient to cause marked displacement of the fractured end of the upper fragment by flexing it into the popliteal space, requiring fixation of the whole leg in flexion until consolidation has become well advanced, or section of the hamstring-tendons, to overcome the tendency to displacement. The head of the fibula, in isolated fracture of that bone, may likewise be drawn upward by the biceps muscle away from the main portion of the bone for an inch or more.

Fractures involving the shafts of the leg-bones commonly exhibit a tendency to anterior angular displacement from the contraction of the

muscles of the calf, which draw the lower fragment upward and behind the upper, or in front of it, according to the direction of the obliquity of the fracture-line. Rotary displacement (Fig. 288) is likely to occur from the falling to one side of the unsupported foot.

The *lower ends* of the bones are the frequent subjects of crushing injuries that cause multiple, often compound, fractures that involve the ankle-joint; but the most common injury is simple fracture of the fibula near its lower end, with avulsion of the tip of the internal malleolus, and either laceration of the lower tibiofibular ligament or tearing away

FIG. 290.—Fracture through lower third of the shaft of the tibia; posterior upward displacement of the lower fragment (Frazier) (skiagraph by Goodspeed).

of that portion of the tibia into which it is inserted, due to cross-breaking strain resulting from forcible eversion of the foot. The typical condition is shown in Fig. 291.

In more extreme cases, in which to the everting force is added a vertical pressure, as in some falls upon the feet, the astragalus is driven upward, displacing upward and outward the fibular fragment and its attached sliver of tibia.

Forcible inversion of the foot may also tear off the external malleolus, and in extreme cases the tip of the internal malleolus also. Such injury is, however, of great rarity.

Fracture of the shaft of the tibia or of the fibula alone may result

from direct violence. The support given by the unbroken parallel bone prevents much displacement, and, by aiding immobilization, contributes to rapid repair of the injury.

The **prognosis** in fractures of the bones of the leg must often be unfavorably affected by the associated injuries. Simple fractures held in proper apposition usually become firmly enough consolidated to bear the weight of the body in walking in from six to eight weeks. A tendency to edema and venous congestion persists for months in some cases, especially in persons past middle age. Aching after much use is often complained of for a long time. Delayed union in cases of comminuted and of compound fracture is of frequent occurrence. Non-union occurs with a frequency exceeded only by the patella and the humerus.

FIG. 291.—Fracture of the fibula, with fracture of the tip of the internal malleolus and of the fibular articular surface of the tibia from violent eversion of the foot (Pott's fracture) (Hoffa).

Treatment.—Fractures of the leg are best treated by some form of plastic splint, or by the posterior wire splint (Fig. 292), after correction of any displacement by traction and manipulation. Persistent recurrence of displacement due to obliquity of the fracture and muscular spasm calls for relaxation of the affected muscles by position or by tenotomy. Division of the tendo Achillis may be unhesitatingly resorted to for overcoming deformity caused by contraction of the calf-muscles. If the fracture is unattended by much laceration or contusion of the soft parts, a plaster-of-Paris roller bandage may be at once applied over a single layer of cotton wadding by which the part has been first wrapped (see section on General Considerations, page 506). Careful watch of the toes, always left exposed for observation, should be maintained at first, until it is evident that there is no impediment to the free circulation of blood in the parts distal to the fracture. Should numbness, or lividity, or pallor of the toes develop, the splint should at once be cut open throughout its length, and sprung open sufficiently to relieve the constriction. The plaster roller should never be primarily applied to a case which cannot be thus watched. If the plaster bandage is well borne, the patient may be allowed to get up from bed and move about upon crutches with considerable freedom as soon as the primary pain and tenderness occasioned by the traumatism have subsided. Whenever, by reason of the absorption of effusions or the atrophy of tissue, the plaster case gets loose, it should be removed and another applied. In any case it should be taken off at the end of the first week for inspection and readjustment, if necessary, of the fracture, and, everything being favorable, a new bandage applied. If the injury to the soft parts is such as to make the safety of the

immediate application of the plaster roller questionable, a posterior plaster gutter, as advised in the case of the patella, should be resorted to. The splint should extend from above the knee to the base of the toes, and should leave the anterior third of the leg exposed (see Fig. 293). It is best held in place by a many-tailed bandage which permits the frequent inspection of the site of fracture without any disturb-

FIG. 292.—Fracture of leg immobilized in a posterior wire splint.

ance of the fragments. When the swelling has subsided, usually during the second week, the plaster roller bandage may be substituted for the gutter.

Special care is to be exercised in the application of these dressings that the foot be kept up to a right angle with the long axis of the leg, and that no lateral deviation occur, the head of the first metatarsal

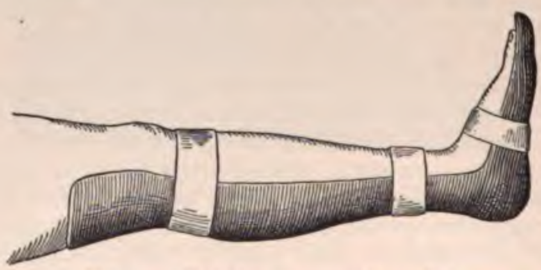

FIG. 293.—Posterior gypsum gutter-splint.

bone being in the same line with the inner edge of the patella and the anterior superior spine of the ilium.

For the temporary fixation of the fragments, until place and materials for the plastic dressings can be procured, well-padded strips of board secured to the limb by circular turns of bandage will serve a good purpose. Three strips, one posterior and one for each side, should be used; they should extend from the middle of the thigh above to beyond the sole of the foot below; they should be so padded

as to fit the inequalities of the limb when snugly drawn up to it by the bandage; they should be wide enough, so that the encircling bandage when applied should not touch the leg. For the special care required in the treatment of compound fractures, see page 508.

Ambulatory Dressings.—In cases suitable for the application of the plaster bandage, it is possible so to adjust the dressing that the portion

FIG. 294.—Ambulatory dressing for fracture of the bones of the leg.

of the limb distal to the fracture may be suspended in the rigid dressing which has been made to extend beyond the sole of the foot below by interposing an inch thickness of cotton between the sole of the foot and that portion of the bandage which comes in contact with the ground, the upper part of the dressing grasping the prominences about the knee and the conical surfaces of the thigh, so as to transmit the weight of the body from them through the splint to the ground, without disturbing the seat of fracture. The swinging, dependent position of the limb and the muscular movements required in the efforts to use such a limb actively in locomotion produce nutritive conditions more

favorable to repair than those which attend the anemia caused by the elevated position, the bandaging, and the disuse which are a part of the methods of treatment usually followed. Special watchfulness against possible pressure-necrosis is required in the use of such a dressing, and it should not be ventured upon in cases in which the prominences about the knee are excoriated or edematous.

For its proper application practical familiarity with the ordinary application of the plaster bandage is requisite, and it is not to be recommended for use by the general practitioner. In the hands, however, of surgeons who have the necessary technical skill and experience, this ambulatory dressing may be applied in most cases of simple fracture of the leg, with the result of avoiding in many cases the disadvantage of prolonged detention from the activities of life, of expediting the full consolidation of the fracture, and of securing an earlier restoration of the full functions of the limb.

The Bones of the Foot.—Fractures of the **astragalus** or of the **os calcis** are more commonly the result of a fall from a height, the weight of the body being received squarely upon the sole of the foot. Some comminution is the usual accompaniment, and dislocation, often compound, is a frequent complication. A portion of the os calcis may be torn off by violent contraction of the calf-muscles. Crushing injuries from direct violence may present every degree of comminution of these bones and laceration of the overlying soft tissues.

In the case of compound injuries not requiring amputation, excision of loose fragments, and even of the entire astragalus, may be indicated. In the less severe injuries, after the fragments have been moulded into place, retention is best secured by a plaster-of-Paris bandage, especial care being taken that the foot, when fixed, is flexed at a right angle to the leg. When the contraction of the calf-muscles tends to draw away a fragment of the os calcis, section of the tendo Achillis should be made.

The **metatarsal bones** and the **phalanges of the toes** are frequently the subjects of crushing injuries, calling for amputation or for excision in their treatment.

CHAPTER XVII.

INJURIES TO THE JOINTS; DISLOCATIONS.

INJURIES TO THE JOINTS.

THE joints, although strong and well arranged to resist violence, none the less, as the parts of the body in which mobility is greatest, form weak points in the economy, and as such furnish the subject of an important chapter in the surgery both of injury and disease.

Importance of Injuries to the Joints.—This is to be regarded first as to the degree of immediate local injury. This may be so severe or complicated by so extensive coexistent damage to the soft parts as to endanger the safety of the limb; or, on the other hand, the structures proper to the joint itself may alone materially suffer. Such injuries may be completely recovered from, or they may leave behind them a tendency to recurrent inflammation, a certain degree of physical weakness, or a varying degree of interference with the normal range of motion of the joint.

The special importance of the slighter injuries to the joints lies, however, in their relation to the various constitutional diatheses, wherein even a very slight trauma may lead to the most serious results. This connection is perhaps most strikingly exemplified in tuberculous disease. Here the number of cases in which the affection dates from an injury often marked by insignificant immediate results is astonishingly great. Though less frequent, yet not less important is a similar history in the case of joint-suppuration secondary to acute infective bone-inflammation in the young. Again, the course of joint-injuries may be seriously influenced by the gouty or rheumatic diathesis, and still more importantly by the hemophilic. A form of arthritis destructive in character is, moreover, sometimes induced in old persons or even in adult life, best known as chronic traumatic arthritis.

Contusions.—These injuries are common, and vary considerably in severity and importance. The superficial position of some articulations renders them liable to considerable contusion as the result of comparatively slight violence, while others are protected by their deep situation. As in so many other instances, the knee-joint takes the first place in this respect, in consequence of its exposed and superficial position, its functional importance, and its size and strength.

Contusions are either caused by blows with blunt bodies, or are the result of striking the joint against the ground in a fall. In the slighter forms these injuries are followed by superficial ecchymosis and a varying degree of joint-effusion, the fluid consisting of an admixture of blood and synovia in different proportions. Such effusions are usually attended by the appearance of local swelling, heat, and more or less pain from tension—the signs, in short, of simple synovitis, the direct

result of trauma—and perhaps by the presence of blood in the joint-cavity. In the absence of any diathetic complication, the ordinary course is to resolution.

From the nature of the violence producing them, however, contusions of the joints are often complicated by very severe injury to the surrounding soft parts—the skin, subcutaneous tissue, the bursæ, the muscles and tendons, the vessels, the nerves, or the bones being more or less implicated. In many of these instances the joint-lesion takes a secondary place. Effusion into the bursæ, of the same nature as that within the articular cavity, often complicates a joint-contusion, and may lead to some difficulty in diagnosis, the bursa, as the more superficial structure, sometimes giving rise to the more prominent initial signs and symptoms. Small fragments of the bones or cartilages may be broken off, too insignificant to lead to the case being classed as one of fracture, but yet, in view of possible after-results, needing an equal amount of care in treatment.

The ordinary course of these injuries, when occurring in healthy persons and moderate in degree, is to resolution and complete recovery. Certain after-consequences, however, are common; the least important of these is the persistence of local pain, with some consequent limitation of function. Again, simple effusion may persist for some considerable time. When portions of the bone or cartilage are broken off, these may so unite as to interfere with the proper movements of the joint, or they may remain as loose bodies, giving rise to the ordinary train of symptoms observed when these are present. With regard to the latter point, however, it should be noted that separation of loose fragments is rare in the absence of previous pathological change, a change which is usually of the nature of chronic rheumatoid arthritis, in which the articular margins are unduly prominent.

Treatment of Contusions.—Slight contusions are best treated by rest and the application of cooling lotions or by hot bathing; more severe ones, by a back splint and an ice-bag or Leiter's tubes. In cases, however, where ecchymosis is a prominent feature, great caution should be exercised in the application of ice, since the lowering of the temperature may so interfere with the vitality of the skin as to lead to gangrene. If effusion is the prominent symptom, no better treatment can be adopted than the immediate application of a plaster-of-Paris splint; but this, as a rule, should not be kept on for more than a few days, as too prolonged fixation may lead to troublesome stiffness of the joint. When the splint is removed, hot bathing and gentle exercise will help to ensure the early resumption of the normal mobility. If the treatment needs to be at all prolonged, massage is most useful. This may be commenced while the joint is still tender, but in this stage it should be directed to the muscles acting on the articulation, and not to the tender joint itself.

Sprains of Joints.—This term is used to describe injuries of joints resulting from forcible movements in which the normal range is exceeded. Sprains may be produced by false movements, too great voluntary muscular efforts, or by blows or falls. Such injuries may result in mere nipping of the synovial fringes, in more or less extensive rupture of the ligaments, or in separation of small fragments of

bone together with the latter structures. Sprains are also necessarily attended by much stretching of the tendons and tendon-sheaths surrounding the articulation.

The immediate result is the establishment of an abnormal degree of mobility, and hence weakness and want of proper stability. This condition is accompanied by pain, and is followed by effusion into the joint-cavity, and often also into the tendon-sheaths surrounding the joint. At a later date ecchymosis occurs, when the deeply effused blood has had time to make its way to the surface.

Results of Sprains.—Much that has been said as to the results of joint-injuries in general, and as to the results of contusions, applies equally well in the case of sprains. One result, however, must be specially mentioned—namely, the persistent weakness due to abnormal mobility. This may depend on the stretching of the ligaments due to long-standing effusion, to insufficient repair of an injured ligament, or to the stretching of the new cicatrix. Careful fixation of the joint at the time of injury is therefore the special indication in the treatment of these injuries.

Treatment of Sprains.—Here again much that has been said as to the treatment of contusions applies, but two points need special mention—first, that effusion is often a prominent sign; and secondly, that every effort must be made to prevent the persistence of abnormal mobility. Both conditions are best treated by immobilization in a plaster-of-Paris splint. For effusion alone, this should not be long retained; but when rupture of ligaments has been diagnosed by the presence of abnormal mobility in any direction, it may need to be continued three or more weeks. The splint is best made of Bavarian flannel, so as to allow of its being tightened up or removed as swelling decreases or massage is thought desirable. In the case of the great weight-bearing joints, such as the knee, a leather support with lateral hinges, so as to allow of flexion and extension of the joint, and yet fully control any lateral movement, is often useful when the plaster is removed. It may be worn several months with advantage.

Massage should be begun early, in order to avoid, as far as possible, weakness of the muscles, and to ensure security to the position of the joint by the retention of a proper tone in them. As in contusions, the rubbing should be applied to the muscles while the joint itself is too tender to bear direct manipulation; and, in fact, it is to the muscles rather than to the joint itself that this treatment is the more useful. In some cases, particularly the ankle and wrist, effusion into the tendon-sheaths around the articulation may be a more prominent feature than the joint-effusion itself. The same treatment in the main should be adopted, bearing in mind the necessity of earlier movement in the case of the tendon-sheaths, and the special efficacy of frictional treatment. Beyond massage, properly limited and graduated exercises, so arranged that the supporting tendons are braced, while the damaged part of the joint-capsule is not stretched, are of great value.

A word of warning should be added here as to the treatment of these injuries when they occur in gouty subjects. Very considerable inflammatory signs are often developed, so as to arouse the suspicion of suppuration. Such cases should be treated with the utmost caution,

and on no account should an incision be made without absolute conviction of its necessity, since such a procedure often gives rise to widespread cellulitis and prolonged suppuration.

Wounds of Joints.—These may be punctured, incised, contused, or lacerated; and their relative gravity depends on the possession of one or other of these characteristics, and on the nature of the instrument by which they have been produced.

Signs of Wound of a Joint.—When a wound is of the punctured variety, small, very oblique, or complicated by extensive laceration of the skin, situated at some little distance from the joint itself, some difficulty may arise in determining whether the articulation has been opened or not. The pathognomonic sign is the escape of synovial fluid. This is usually sufficient proof, but it is by no means always present; and beyond this we have to bear in mind the possible escape of small quantities of similar fluid from bursæ or tendon-sheaths in the immediate vicinity. Giving full importance to this sign, therefore, when it exists, we have often to decide in its absence, and then depend mainly on the history of the case, careful examination of the wound, the position of the opening, and on the occurrence of rapid effusion of either synovia or blood into the joint-cavity.

Suppuration of a Joint.—The occurrence of synovitis in a varying degree is to be expected in most cases, and the injury begins to acquire special importance only when further changes lead us to suspect the advent of suppuration. The mode of onset of this may vary considerably. In the most acute cases the temperature at once rises to 102° F. or more, often with the concurrence of a rigor, and always with a decided increase in the amount of pain experienced. Meanwhile the pulse steadily gains in frequency and acquires a bounding character. Swelling of the joint becomes more marked, the tension often becoming extreme; redness and edema of the surface appear. The pain is acute, constant, and accompanied by exacerbations due to the relaxation of the spasmodically contracted muscles, which latter give rise to sudden starts that destroy any chance of the patient's obtaining proper sleep.

If unrelieved, the process extends, infection travelling by the original route of the wound into the areolar planes in the neighborhood of the joint, and into any bursal extensions which may exist. The extension may be so widespread as to involve the whole limb, if the patient's strength holds out long enough; but, on the other hand, it may be checked by timely incision of the joint and the affected area of the limb. Together with the extra-articular changes, continuous destruction proceeds within the joint itself, the synovial membrane becomes transformed into a mass of granulation-tissue, or sloughs; the cartilages become eroded and separated, and the bones denuded of their periosteum. These local processes are accompanied by a continuance of the general symptoms already detailed; the temperature may rise to 104° or 105° F., and profuse perspiration occurs at night. The pulse gains in rapidity and loses in strength, the appetite is lost, the tongue becomes dry, furred, and brown, and pain and the drain due to the suppuration rapidly produce exhaustion. Again, a fatal termination may be hastened by the supervention of septicemia or pyemia.

In other cases, the process is by no means so acute in its onset or

subsequent progress. The first signs of trouble are a slighter rise of temperature, acceleration of the pulse, and a less amount of swelling and pain. If an opening exists by which synovial fluid escapes, this will be first noticed to contain flakes of lymph, and later become purulent; or similar characters will be noted in synovia drawn off with the aspirator. If uninterfered with by treatment, the further changes may resemble those already detailed, the various stages being only more slowly developed.

Results of Wounds of Joints.—The immediate results of wounds of joints have been considered in the preceding paragraphs, it only remains to say a word concerning the more remote. First, should a large joint suppurate, the serious attendant illness must set a material mark on the constitution of the patient; secondly, even the slighter forms of inflammation may be followed by troublesome stiffness of a more or less permanent nature, and in the severer forms this may amount to complete ankylosis, either of the fibrous or the bony variety. Again, the termination of the period of acute suppuration may be only the commencement of a chronic arthritis of indefinite duration.

Treatment of Wounds of Joints.—When the wound is small, the first point for decision is whether the joint should be opened up and thoroughly disinfected. In deciding this question, we are mainly influenced by the nature of the instrument that produced the injury. If this was small and, as far as we can judge, clean, the best course is to seal the wound, place the limb upon a splint, and await events. If the wound is larger, it is better at once to take steps to render both the wound and the joint itself as aseptic as may be in our power. The next question is that of drainage. If this be decided upon, the tube should be inserted at the most dependent part of the articulation. In many cases it is preferable to close the joint, apply pressure, and, in the event of free effusion, to insert a director, and thus evacuate the fluid and relieve tension, this procedure being repeated as often as may prove necessary. In any case, if a tube is inserted, it should be dispensed with as soon as possible.

The wound once healed, the further treatment of the case is that of a simple one of traumatic synovitis. If we should fail in our first effort to asepticize the joint, and suppuration should follow, the articulation must be incised and thoroughly drained. The sooner this is undertaken, the better chance there is of preventing widespread infection of the surrounding tissues and the development of hopeless destructive changes in the joint. This most important step having been taken, the next question is the best mode of dressing the wounds. Three forms of treatment are open to us: 1. To dress frequently, so as to remove all discharge at the earliest moment possible; 2. To set up a constant irrigation-apparatus; 3. To place the patient or the limb in an antiseptic bath. The main objection to the first plan is the exhaustion often caused to the patient by the process of dressing; nevertheless, this is sometimes necessary, and if the joint drains freely and the discharge is not very abundant, it is often the best plan. Constant irrigation often gives excellent results; but this also is exhausting to the patient, especially if a large joint is affected. If chosen, it should be arranged with a tank of antiseptic fluid kept at a uniform

temperature of 100° F., the fluid being conveyed across the joint by properly arranged tubes. The process may then be continued for several days with intermissions. Both it and the next method are particularly indicated where there are abundant suppuration and sloughing. The constant bath is most useful in the case of the small joints of the extremities, or in children, whose entire bodies may be immersed, the temperature of the fluid being carefully regulated. Excellent results are to be obtained in suppurating knee-joints in children by this method, the limb being placed on a back splint in the bath. The best fluids to employ are those of a non-poisonous character, such as boric-acid lotion, or creolin 1 : 300 or 400, especially the latter. If perchlorid lotion is employed, it must not be stronger than 1 : 5000, and great care must be taken to watch the patient narrowly. Neither irrigation nor bath-treatment should be continued if the limb becomes sodden.

During the carrying out of these local methods, the patient should be kept up by the free administration of fluid nourishment, combined with a sufficient supply of stimulant; quinin may be administered internally. If the organism causing suppuration should be proved to be a streptococcus, the question of the employment of antistreptococcic serum must also be considered, especially if the constitutional symptoms are severe. Should our efforts to check the mischief fail and the patient shows signs of sinking, amputation may be necessary.

DISLOCATION OF JOINTS.

This term is applied to the condition in which one or other of the bones entering into the formation of an articulation is permanently displaced. The dislocation takes its name from the distal of the two bones; thus, a dislocation of the shoulder-joint is understood to mean a displacement of the humerus.

Dislocations are most conveniently classed according to their causes, and by this method the following four varieties may be distinguished: 1. Traumatic; 2. Congenital; 3. Spontaneous; 4. Pathological.

Beyond this, dislocations are sometimes spoken of as complete and incomplete.

The comparative frequency of dislocation of the individual joints differs greatly, the variation depending mostly on the anatomical disposition of the joint, the age, sex, and occupation of the patient. The statistics given on page 595, compiled from the records of St. Thomas's Hospital, London, offer a very fair view of the influence of these factors, since great care has been taken to include all dislocations of the upper extremity treated at the hospital.

Causation.—As indicated in the classification of dislocations given in the table (page 595), the displacement may be the result: I. Of external violation; II. Of muscular action; III. Of pathological changes in the ligaments; or IV. Of a congenital deficiency in the development of the joint.

External Violence.—This may be direct in its nature, when the articular end of the bone is driven against a limited portion of the capsule, which gives way at that spot and allows the escape of the bone in a corresponding direction. The further course may be influ-

enced by the continued exertion of the violence, the force of gravity, the normal elasticity of the muscles and other structures surrounding the articulation, and the amount of injury to surrounding parts; but in all cases its final direction and extent are determined by the portion of the capsule which remains intact. Direct violence is responsible for a considerable proportion of the less common dislocations, such as those of the humerus backward, or of the tibia from the femur.

Table of 812 dislocations treated at St. Thomas's Hospital in eight years.

BONE.		SEX.		AGE.									SIDE OF BODY.		
Percentage of occurrence.	Total.	M.	F.	−5	−10	−20	−30	−40	−50	−60	60+	Unstated.	R.	L.	Unstated. Bilat.
Lower jaw, 4.18%	34	16	18	..	1	3	14	8	3	2	2	1	4	9	21
Clavicle, 4.19%	34	27	7	..	3	4	12	5	3	3	3	1	15	12	7
Humerus, 43.47%	353	241	112	1	..	6	39	50	65	73	78	41	173	169	11
Radius and ulna, 19.45%	158	136	22	1	41	79	9	13	5	3	..	7	63	91	4
Radius alone, 3.69%	30	22	8	9	7	10	2	2	..	..	..	...	14	16	...
Ulna alone, 1.6%	13	9	4	1	4	5	1	2	..	..	..	...	6	7	...
Carpus, 0.98%	8	7	1	..	2	4	1	..	1	..	..	...	3	4	1
Thumb—all joints, 9.1%	74	58	16	2	5	7	20	19	8	6	4	3	34	39	1
Fingers—all joints, 10.59%	86	62	24	3	5	21	20	19	8	6	4	...	42	43	1
Femur, 1.23%	10	7	3	3	3	1	1	..	1	..	1	...	..	..	10
Tibia, 0.123%	1	1	..	..	..	..	..	..	..	1	..	...	..	..	1
Patella, 0.24%	2	1	1	..	..	..	..	..	..	..	..	2	..	..	2
Tarsus, 0.86%	7	6	1	..	..	..	1	4	1	..	..	1	..	..	7
Astragalus, 0.24%	2	1	1	..	..	..	..	1	..	..	..	1	..	..	2
	812	594	218	20	71	140	120	123	95	94	92	57	354	390	68

The whole table comprises 812 dislocations, of which 756, or 93.1 per cent., occurred in the upper extremity, 22, or 2.7 per cent., in the lower extremity, and 34, or 4.18 per cent., were of the lower jaw. Dislocations of the spine are not included.

Indirect violence is a much more fruitful source of dislocation, the force being applied at some distance from the affected joint, and the leverage exerted corresponding either with the length of the bone or often of the whole limb. A very great majority of the more common dislocations of the type-forms are produced in this manner, certain definite portions of the capsule being especially liable to rupture in the different joints, and the permanent position of the displaced bone depending on the same factors that have already been enumerated in speaking of dislocations from direct violence. Such dislocations are naturally less liable to be accompanied by severe local injury to the soft parts. Indirect violence in almost all cases carries a natural physiological movement beyond its normal limit; and it may be noted that of all movements, that of forced abduction is the most generally dangerous.

Muscular Action.—What has been said of dislocation by indirect violence holds almost equally well for the explanation of dislocation by the forcible contraction of the muscles. The only distinction is that the range of leverage which can be exerted is not so great. Thus, many such dislocations, notably that of the mandible, really depend on a very slight exaggeration of the normal physiological movement of the joint. Such dislocations are not uncommon in convulsions from epilepsy or other causes, or may be the result of forcible use of a limb, as in striking out the fist, or in lifting heavier weights than the individual's strength warrants.

The occurrence of certain **conditions generally favoring dislocations** must be here briefly considered.

Anatomical Peculiarities and Exposed Position of the Joint.—These will be dealt with under the heading of the Special Joints. It suffices here to point to the dislocations of the shoulder-joint as the most striking exemplification of these influences.

Age.—Taken as a whole, it is no doubt correct to say that the predisposition to dislocation increases steadily from the first decennium upward, and in the table on page 595 this point is practically borne out.

The comparative infrequency in children is to be explained by the fact that the attachment of the joint-capsule is of a stronger nature than the connection between the epiphysis and diaphysis; hence, experience has shown that the traumatic separation of the latter in part takes the place of dislocation. Again, the slighter body-weight, greater elasticity, comparative weakness of the shafts of the bones, and freedom from laborious occupation in childhood are all unfavorable to the occurrence of dislocation.

The increase in strength and aptitude in the muscles concomitant with the years of most active existence lowers the danger in adult life, while with the approach of old age the gradual atrophy of the bones and ligaments and the loss of elasticity of the muscles lower both the capacity to withstand violence from without and the capability of avoiding it. As has been pointed out by Krönlein, the relative frequency in old age is far greater than the actual, if the number of dislocations is compared with that of persons of fifty years of age and upward, since the latter is naturally small compared with the number under that limit.

Sex.—As in the case of most traumata, the male sex is far the more liable to these accidents, on account of the more active nature of the occupation pursued. In the St. Thomas's table of 812 dislocations, 594, or 73.1 per cent., occurred in men; 218, or 26.6 per cent., in women.

Occupation and Degree of Muscular Education and Development.—The occupation of the individual necessarily exercises a most important influence on the liability to dislocation.

Many callings, from their intrinsic nature, expose the individual to chances of external violence quite outside the experiences of ordinary life. But against this we have to put the fact that persons whose work needs great muscular effort are usually well developed and able to bear safely strains which would be of great danger to the ordinary individual. Again, it is not only a question of mere strength, but also of what may be called education. It has been remarked by Sir Astley Cooper that, given a contracted state of the muscles, a dislocation is an impossibility; and there exists no doubt that those whose calling depends mostly on the use of the muscles possess a capacity to withstand strain far above that possessed by those whose occupation is of a lighter or more sedentary nature.

Lastly, the occurrence of dislocation in some individuals may be facilitated by the existence of an abnormal laxity of the ligaments and soft structures, or deficiency in the conformation of the bone-extremities.

Cases are seen in which a joint may be dislocated in varying degrees, and this aptitude may be cultivated even by particularly powerful subjects, the ligaments elongating as the result of graduated strain.

Pathology.—The all-important feature in dislocation lies in the injury to the capsule. The position of the rent determines in great measure the direction taken by the displaced bone, while upon its extent depends the distance to which the bone may travel, the intact portion of the capsule being the main check to the passage of the bone into other than typical positions. Again, a small rent in the capsule may be the chief obstacle to reduction in difficult cases, while

very free laceration may result in difficulty in maintaining the replaced bone in position. The direction of the rent may be oblique in the axis of the joint, or it may be transverse to this axis. In the latter case, it usually lies near to the surface of the bone which forms the cavity; in the former case, it often occurs at a definitely weak portion of the capsule, such as the under and inner portions of the ligament in the hip- and shoulder-joints.

Certain portions of the capsules are very rarely torn. These usually correspond to definite strengthening bands, such as the ilio-femoral of the hip or the coracohumeral of the shoulder. The escape of these bands from injury, of course, depends chiefly on their intrinsic strength, and its importance cannot be overestimated, since upon their limiting influence depends the position taken up by the displaced bone, a point amply proven by the experience gained in producing the various dislocations experimentally on the dead body. When the capsule is completely rent, one of the so-called atypical positions is the result. While removing from the muscles the function of determining the position taken up by the displaced bone, we must none the less bear in mind that the rigid contraction which takes place to maintain the parts at rest and relieve pressure-pain forms one of the main obstacles to reduction.

Beyond the injury to the joint-capsule, varying degrees of laceration may occur in the several soft structures surrounding the articulation, or even fracture of the bones themselves. The more common forms of injury to the soft parts consist in more or less contusion and ecchymosis of the skin, this being the more marked when the injury is due to direct violence; in contusion and laceration of the subcutaneous and deeper planes of connective tissue; in contusion and laceration of the muscles, and rupture or separation of tendons from their attachments. Less commonly, dislocation may be complicated by pressure, contusion, or rupture of the main artery or vein of the limb or one of their large branches. The accidents, with their attendant risks, will be again referred to under the heading of those special dislocations in which they are most commonly met with. They may be followed by gangrene of the limb, death from internal hemorrhage, the development of traumatic aneurysm, or thrombosis.

Injuries to nerves are comparatively rare. They may be followed by more or less permanent paralysis, according to whether the nerve has been contused, suffers permanent pressure, is stretched, or has been completely ruptured. Again, primary injury of the nerve may be followed by the development of secondary neuritis, producing similar symptoms.

The commonest form of injury to the bones is the so-called "fracture par arrachement" of Maisonneuve. In this the portion of bone to which a ligament is attached is separated, or one or more of the bony prominences in connection with the joint is torn off by the tendon inserted into it. A less common form is that in which a portion of the margin of an articular cavity is broken off or the floor of the cavity perforated. Beyond these intrinsic injuries, a distant fracture of one of the bones entering into the articulation, or one adjacent to it, may be caused by the same violence.

Lastly, a dislocation of one of the bones of the trunk may be complicated by injury to the neighboring viscera. Thus, the sternal end of the clavicle occasionally presses on the trachea, or a dislocated vertebra on the spinal cord.

The occurrence of a dislocation is always followed by the development of a certain degree of synovial effusion, the synovia being more or less abundantly mixed with blood. Such effusion is usually quickly absorbed, but it may occasionally be very abundant—a matter of some importance, as it may facilitate the recurrence of a reduced dislocation, if proper means are not taken to keep the bones in position. The blood effused into the surrounding tissues is also usually rapidly reabsorbed. It serves also as a basis for the development of the cicatricial tissue necessary for repair of the capsule and other damaged structures. The rent in the capsule is, however, closed by tissue far weaker than the normal ligament, more capable of distention, and more liable to rupture on comparatively slight strain; hence the importance of previous dislocation in the event of future injury. The torn muscles and tendons heal, but when the latter have torn away pieces of bone with them, the repair of the fracture is seldom exact. This may lead to serious subsequent limitation of the range of movement of the joint.

Signs and Symptoms of Dislocation.—These are most conveniently divided into classes: 1. Those visible on inspection; 2. Those to be determined on palpation and manipulation; 3. Those dependent on interference with function of the joint and pressure by the displaced bone on surrounding structures.

Inspection.—By this is determined the general position of the member, alterations of contour, the projection of certain bony prominences and the absence of others, and, finally, apparent alterations in the length of the limb, which may be substantiated or otherwise by actual measurement.

Palpation.—By this is ascertained the altered relation of various fixed bony points, and the recognition of those which are unduly prominent; in addition to this is determined the absence of others from their normal positions, often accompanied by a feeling of "hollow tension" of the investing soft parts and the presence of the displaced bone in an abnormal position.

Interference with Function.—This is determined by first asking the patient to perform certain movements voluntarily, and then making similar ones passively, thus estimating how far the normal functions are limited, and in what directions.

To the signs above enumerated we may add the existence of pain, much exaggerated by movement, especially marked where nerve-trunks are pressed upon, and sometimes special symptoms due to the pressure of the displaced bone on the vessels or neighboring viscera. Lastly, it must be borne in mind that all the usual signs may be more or less obscured by swelling due to contusion and local injury.

Diagnosis.—From Contusion or Sprain.—It suffices here to say that all the definite signs of dislocation are absent; but that, on the other hand, the nature of the injury suffered, the pain, swelling, and interference with function may suggest the possibility of its presence. In such cases the first step is the careful exclusion of all signs, and if

doubt still exists, the administration of an anesthetic, which will clear up all chance of error. In such cases too much care cannot be given to the inspection of the case, the patient being sufficiently uncovered to allow a thorough comparison to be made with the corresponding part on the other side of the body.

From Fracture.—As to the broad distinctions, it should be remembered that in dislocation the normal range of movements is limited, while slight mobility in abnormal directions may be present; in fracture, the mobility is increased. In dislocation the deformity, if removed, does not return; in fracture it does. The deformity of the limb in dislocation is not so evidently the result of the action of gravity as in fracture. Pain is, generally speaking, more widely diffused in dislocation, more localized in fracture. Beyond this, the cardinal symptom of fracture—"crepitation"—is usually absent in dislocation.

From Pathological Conditions.—Infantile paralysis or certain myopathic conditions may apparently simulate dislocation. As a general rule, however they are readily to be discriminated by attention to two points—the condition of the muscles which are atrophied and often shortened, and the fact that the displaced articular end can be replaced with ease, and when released returns to its former position. From *congenital dislocation*, the discrimination will depend on the history, the deficient development of the joint-ends and of the limb generally. The spontaneous displacements due to habitual malposition closely resemble the ordinary variety, the history alone being here of diagnostic importance. *Pathological dislocations*, although closely following the type, generally offer little diagnostic trouble, if the history is carefully taken. The only real difficulty occurs in the case of joints affected with *osteoarthritis*. Patients affected with this disease often suffer little until the pathological changes are fairly advanced, in which case an injury, by aggravating their symptoms, first brings the joint under notice. Attention to the absence of the typical signs of dislocation, and the presence of other bony changes than that which gives the appearance of dislocation, together with the condition of the synovial membrane and muscles, will here be our most important aids.

When available, the employment of the *X*-rays is an invaluable diagnostic aid, especially in the smaller joints. With these not only the position and extent of dislocation can be determined, but also the presence or absence of coexistent fracture. If a fluorescent screen is at hand, this is by far the preferable method, as the joint can be examined both before and after manipulations for reduction. Where a skiagram is taken, at least two positions should be tried, usually a lateral and an anteroposterior one; and great care is necessary to prevent the occurrence of a distorted image due to a want of parallelism of the plate and the limb and proper horizontal passage of the rays. If these precautions are not taken, a very confusing and unreliable result is often obtained. If necessary, a subsequent skiagram is readily taken without the removal of the splint and bandages.

Prognosis.—No dislocation in itself, unless compound or complicated, can be said to be dangerous to life. The question of prognosis, therefore, mainly concerns—first, the possibility of reduction; second, the maintenance of the displaced bone in position; and third, the persistence of after-effects.

As to the first point, recent dislocations comparatively rarely prove impossible of reduction. Occasionally, however, all efforts are fruitless, and under these circumstances, failing operative measures, all that can

be done is to try and ensure as free movement of the bone as possible in its new position.

Proper precautions rarely fail to ensure the maintenance of the replaced bone; but it is well to bear in mind that especial care is necessary to render the patient safe from this accident, if there is reason to believe that the capsule has been extensively lacerated, or if the injury is the cause of very free effusion into the joint.

The first after-effect, the occurrence of synovitis, is seldom of any great importance except as taking its part in the production of the commonest of all troubles, a greater or less degree of stiffness, due to the formation of synovial adhesions, and the contraction of the cicatricial tissue formed in the process of healing of the original injury. These troubles, however, in the absence of unusually severe primary damage, are generally to be obviated by the sufficiently early employment of passive movements, combined with massage. Stiffness and loss of function are necessarily much more frequent and troublesome to deal with if the dislocation is complicated with an hysterical temperament or actual injury to the nerve-trunks.

The most serious after-effect is the acquisition of a tendency to recurrence. The commonest cause of this is the stretching of the cicatricial tissue which closes the capsular rent, and as evidence of this, it has been generally found, when opportunity has arisen, either in the course of an operation or post-mortem examination, that the capsule is considerably wider and more roomy than normal. Unfortunately, this is an inevitable result in the case of many working men, but none the less it should impress the importance of careful regulation of the amount of work that is undertaken by the patient during the first few months after the original injury. In other cases recurrence depends on causes over which we have little or no control, and among these may be especially mentioned very extensive or complete ruptures of the capsule, and the failure of fragments of bone to unite when they are torn off by the tendons in the so-called "fractures par arrachement."

The question of compound and old dislocations will be considered at the end of this chapter.

Treatment.—The treatment of dislocation necessarily consists in its reduction. For the attainment of this end, several methods are open to us. The most important of all rules for the treatment of these injuries is that a dislocation of any bone should be returned by the method that necessitates the least possible force, and hence the least possible chance of further lacerating the already damaged structures.

The method always to be tried first, therefore, is the gentle correction of the false position assumed by the displaced bone, combined with slight traction in its axis, and possibly movements of internal or external rotation. Failing this method, we have manipulation-maneuvers and extension to fall back upon. Of these, manipulation is the more scientific, since, especially in the case of the hip- and shoulder-joints, the methods are founded on an accurate knowledge of the injury probably existing and of the structures which remain intact. The theory of the manipulation-methods is—first, to lift the displaced articular extremity from its false position by employing an intact part of the capsule as a fulcrum; second, by rotatory movements to ensure the gaping of the rent in the capsule; third, to bring the articular end opposite the rent; and lastly, by a reversal of the movement, to effect the entrance of the displaced bone into its proper position. In the whole maneuver the shaft of the displaced bone is used as a lever, and the power of this will necessarily vary with the length of the bone in question.

The extension-methods consist in a preliminary fixation of the trunk or proximal element of the joint, followed by traction made in the axis of the displaced bone, the latter also being usually utilized as a lever, the fulcrum for which is furnished by a ligament or bony prominence,

or is artificially provided. A sufficient degree of counterextension is obviously necessary. The traction may be manual or, if necessary, exerted by pulleys. All these methods will be more fully dealt with under the heading of the Special Joints.

The after-treatment consists in rest for a variable period, followed by massage and exercises. The rest may be obtained by splints, bandages, or the arrangement of permanent extension-apparatus in cases where splints prove inefficient.

Signs of Reduction.—The effectual reduction of a dislocation is usually indicated by something in the way of a snap, accompanied by a sensation of grating felt by the surgeon as the bones resume their normal relation. Beyond this the injured part should more or less resume its proper outline, corresponding to that of the other side of the body, the possibility of performing passive movements should be perfect, and, most important of all, the relation of the bony points in the neighborhood should not deviate from the normal.

Obstacles to Reduction.—Although responsible in a minor degree only for the position assumed by the displaced bone, yet the muscles, by their contraction, often offer a decided obstacle to reduction. This is to be removed at once by the use of an anesthetic, and needs no further mention.

A more formidable obstacle, however, may exist in the disposition of the rent in the capsule. This may be unusually small and run in an atypical direction, or, on the other hand, it may be so extensively lacerated as to remove our main aid in reduction by manipulation—viz., the intact portion which is employed to act as a fulcrum. Beyond this, portions of the capsule may take up a position across the joint-cavity; a similar position may be taken by a neighboring muscle or tendon, or a bony fragment.

A small rent may be enlarged by cautious manipulation, and a rent in an unusual position may be found by varying our method of manipulation. When wide destruction of the capsule is the difficulty, extension will probably be the best method to try; and we must remember here that if successful, care must be exercised to maintain the bones in their proper position when reduced. The interposition of torn structures is hardly to be met by any general rule; we can only bear in mind the many variations in procedure open to us, and make use of them successively. Operative methods may become necessary if the dislocation cannot be reduced, or, in some joints, when reduction cannot be maintained.

Occasionally, subcutaneous division of obstructing bands will suffice; more often an open incision is necessary, and in a small proportion of cases excision, either partial or complete, has to be resorted to. Recurrent dislocation may be treated by temporary suture of the opposing joint-surfaces. These methods will be more particularly referred to under the special joints; but it may be broadly stated that in certain joints operative measures will not improve the result to be obtained by careful after-treatment, and that in all a careful consideration of the local conditions, as well as of the age, occupation, and general condition of the patient, must precede a determination to resort to them.

One other difficulty should here find mention—the simultaneous fracture of the dislocated bone in the immediate region of the joint. This occurrence, though fortunately far from common, affords one of the most difficult problems in surgery. Several alternatives are open to us. We may put up the fracture and wait for its consolidation before attempting reduction. This, as necessitating a delay of some weeks, is most unsatisfactory, since we must either wait until the chance of reducing the dislocation is problematic, or risk the

chance of re-fracture without succeeding in reinstating the bone in the joint. The immediate application of splints and attempts at reduction have rarely been successful, unless the fracture is at some distance from the joint. Lastly, we have the open method of replacing the bone by incision of the joint and simultaneous wiring of the fractured ends. Given a sufficiently young and healthy subject with good surroundings, there is little doubt that the last is the best method; but, if undertaken, it should be remembered that the operation is often one of extreme difficulty, and necessitates the most scrupulous care if it is not to lead to disaster.

Compound Dislocation.—This accident is fortunately a rare one, and still more so if uncomplicated by fracture. It is most common in the small joints of the hands and foot and in the elbow.

As is the case with compound fracture, the nature of the injury varies with that of the violence exerted, displacement produced by direct violence being usually accompanied by the more severe local injury. Dislocation is, however, the more serious, as in addition to a contused wound we have a synovial cavity laid open, often at the least favorable aspect for the establishment of efficient drainage. As in fracture, a conservative line of treatment is to be adopted, bearing in mind the increased severity of the case and the smaller likelihood of avoiding suppuration. While a purely conservative line of treatment is best, excision or partial excision is in many cases indicated as promising the best chance of obtaining a satisfactory result.

Old Dislocations.—A certain number of dislocations remain unreduced. This failure to secure reduction may depend on omission to

FIG. 295.—Old dislocation of humerus; bony change (St. Thomas's Museum, London).

recognize the nature of the accident on the part of the medical attendant, on neglect of the injury on the part of the patient, or, more rarely, on some of the obstacles to reduction (already enumerated) proving insurmountable. If for any of these reasons the bone remains in its new position, certain pathological consequences result, with the effect of compensating to a certain extent for the interference with function attendant on the injury. In the first place, the soft tissues around the

articulation become consolidated by the cicatrization of the parts injured, and in this way a new joint-capsule is developed. With the lapse of time, this capsule gains consistency, besides firm attachment to the bones, and may become provided with an adventitious synovial lining. Meanwhile, certain changes take place in the osseous elements. The irritation caused by the pressure of the displaced bone leads to the development from the periosteum of a circumferential ring of new bone, which moulds itself to the outline of the articular extremity much as the circumferential margins of the joint-cavities are originally developed, or as a new cavity is seen to develop in the pathological dislocations of the hip with the so-called wandering acetabulum.

FIG. 296.—Skiagraph of fracture-dislocation of elbow to illustrate the employment of the *X*-rays to a limb enveloped by splints and bandages (skiagraph by A. B. Blacker).

The cavity may reach a high degree of development, the bone acquiring a thick, fibrous investment representing the normal cartilaginous covering. In other cases, especially in old persons, the bone becomes smooth and eburnated, as in joints affected with chronic traumatic arthritis. The moulding of the new cavity is mainly dependent on the new bony formation; but it depends in part also on pressure-atrophy, as is proved by the pressure-changes which occur in the displaced bone when it is a prominent articular head, like the humerus. A glance at the illustration of an old dislocation (Fig. 295), exhibiting in the anatomical neck a deep groove corresponding to the point at which it rested against the margin of the glenoid cavity, well demonstrates this point, even when the comparatively cancellous nature of this element of the joint is allowed for. Gradually, with the development of the new joint, obliterative changes proceed in the old one, or in the parts of it no longer functional. The matrix of the cartilage becomes fibrillated, and gradually blends with new fibrous tissue developed in part from old joint-elements, such as strips of capsule, in part from inflammatory new-formation. A consideration of these changes demonstrates to us the difficulty likely to attend the attempted reduction of an old dislocation of anything more than six weeks' duration; but at the same time it must be borne in mind that the rapidity with which they occur in different individuals varies greatly.

The **diagnosis** and **prognosis** in old dislocations will be considered under the accounts of the special joints. As to **treatment,** it is only necessary to point out here that we have two courses open to us, supposing reduction to be either impracticable or inexpedient—either to do our best by the employment of adequate passive movement and massage to promote the formation of a new movable joint, or to have recourse to operative measures.

In attempts at reduction the more forcible methods of extension

and manipulation have usually to be employed; and these are the more likely to be successful if, as a preliminary, the movements have been rendered as free as possible by forcible manipulation, in order that adventitious adhesions may be broken down.

If bloodless methods fail, success may be attained by subcutaneous division of tendons, ligaments, or other tense bands; in other cases it may be as well to proceed at once to open arthrotomy or to resection. If the former is selected, it should be borne in mind that the difficulties preventing reduction by ordinary methods may render reduction after incision equally impossible. Hence we should, as a rule, be prepared to proceed to the more serious operation at the first failure. Resection of the joint is most commonly indicated when the ankylosis is more or less complete, or when the displaced bone gives rise to severe pressure-symptoms. In some cases, a partial resection will suffice, by removing a prominent process of bone, which has been the most serious obstacle to free movement; in others, the resection will need to be a very free one, in order to avoid subsequent ankylosis. Free resection is especially indicated in fracture with dislocation, as of the elbow, where the development of abundant callus has already been an important element.

Accidents during reduction and complications are the same in nature, after attempts to reduce old, as recent dislocations; but it should be borne in mind that attempts at reduction of old dislocations have given us the richest experience of these complications. Therefore, while employing sufficiently forcible measures, very great care must be taken to adapt the force used to the powers of resistance of each particular case.

Pathological Dislocations.—These may be due to a variety of causes, such as excessive effusion into the joint-capsule, weakening or absorption of the ligaments as the result of inflammatory changes of various kinds, or relaxation of the ligaments as a result of shortening or distortion of the intra-articular portion of the bone, secondary to disease. Allied in nature to this form are the displacements occasionally seen as the result of habitual malposition in the very weak or in the insane. The articular end of the bone here presses locally on a capsule deficient in tone, which gradually, or sometimes suddenly, gives way and allows the development of a typical dislocation. The early recognition of the latter displacements is the more important in that they are often capable of reposition and cure.

SPECIAL DISLOCATIONS.

Lower Jaw.—Situated at some depth from the surface and overhung by the zygomatic arch, the temporomaxillary joint is well protected from direct violence; but the body of the jaw and its ramus form a bar of considerable length, which, acted on by indirect violence applied to the body-angle or symphysis, may exert powerful leverage on the structures retaining the condyle in position, and may lead to dislocation. This joint is the articulation of all others prone to displacement from muscular action—a fact readily explained when we remember that the simple action of opening the mouth may be almost regarded as a subluxation of the condyle which a very slight increase in range may convert into an actual dislocation.

Certain conditions specially favor the possibility of dislocation. 1. With the mouth closed the condyles rest in the hollow of the glenoid cavity, but when open, on the convex eminentia articularis. 2. The capsule has to be very loose to allow of the inclusion of the large eminentia articularis, and, besides, it is weak, the only strong band, the external lateral ligament, being sloped downward and backward to allow the forward gliding of the jaw when the mouth is open. The small part taken by the capsule in resisting dislocation is evidenced by the fact that it is never torn when this occurs. 3. The large fibrocartilage necessary for the adaptation of the bony surfaces is provided anteriorly with a powerful insertion of the external pterygoid muscle.

The normal stability of the joint is well shown by the fact that dislocations are only common at an age in which retrogressive changes have led to manifest alterations in both the form and direction of the condyle and the depth of the alveolus.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations, 34 dislocations of the mandible occurred, being 4.18 per cent. of the whole number. In Krönlein's series 10 were observed in a total of 400—that is to say, 2.5 per cent.

Causation and Classification.—Luxations are most frequent as the result of a too extensive movement of the jaw in the acts of laughing or yawning, and therefore are mostly due to muscular action. They are more common in women. Dislocation may, however, be produced in a precisely similar manner by violent manipulation in extracting teeth, introducing a gag or instrument into the mouth, or, more rarely, by blows while the mouth is open. The displacement may be unilateral or bilateral. In the St. Thomas's statistics, 21 were bilateral, 4 were of the right condyle, 9 of the left.

Pathology.—When displaced, the condyles pass forward into the zygomatic fossa, and remarkably little laceration of the structures occurs except of the loose tissues surrounding the joint, even the capsule remaining intact. Difficulty in reduction has been ascribed to locking of the coronoid process against the zygomatic arch, but this has been effectively disproved, the difficulty in recent cases depending on muscular contraction, in old cases on adhesions.

Symptoms.—*Bilateral Dislocation.*—On inspection, the mouth stands fixedly open, and although the jaw can often be somewhat depressed, all attempts at closure fail. In thin faces the swelling of the condyle at an anterior position is often evident, and the contracted temporal and masseter muscles form prominences above and below the zygoma. On palpation, a hollow can be felt anterior to the ear in the usual position of the condyle and posterior to the prominence already noted. On palpation from within the mouth, the coronoid process may be felt in an advanced position. There is much local pain due to stretching and pressure on the branches of the third division of the fifth nerve, which may radiate to the ear and scalp; saliva dribbles from the mouth, as a result of pressure on the salivary glands. The patient is unable to masticate, and the speech is defective.

FIG. 297.—Bilateral dislocation of the jaw.

Unilateral Dislocation.—In this variety the signs are similar, but they are confined to one side, and consequently less pronounced. The mouth is less widely open, and the distortion is asymmetrical from the pushing of the symphysis to the opposite side. On the other hand, diagnostic advantage is gained in having the sound side for the purposes of comparison.

Compound dislocations are uncommon, and are always due to direct wounds over the temporomaxillary joint.

Prognosis.—The reduction of recent displacements is usually easy enough, but if the injury is overlooked, the symptoms gradually become less marked, and mobility increases so as to allow of a modified use of the jaw. After a lapse of three months, there is not much likelihood of successful reduction, but an attempt should certainly be made up to the expiration of six months. The most important point prognostically is the acquisition of a marked tendency to recurrence on very slight provocation.

Diagnosis.—Confusion with any other condition is unlikely, since the change in the patient's appearance is so sudden that hardly any other explanation would meet the conditions of the case.

FIG. 298.—Mode of manual reduction.

Treatment.—Pressure being made on, or in the position of, the last molar teeth by the thumbs of the surgeon (carefully wrapped around with a cloth for protection), a fulcrum situated below the normal center of motion is furnished for the depressed angle by the masseter and internal pterygoid muscles and by the stylomaxillary and lateral ligaments of the joint. A kind of bilateral sling is thus provided, in which the jaw is sufficiently depressed to allow the condyle to reach the most prominent part of the eminentia articularis, when the symphysis is elevated by the fingers, and the jaw is suddenly drawn back and slips into position. In the majority of instances this maneuver can be carried out without the aid of an anesthetic, and in many cases some subjects of recurrent dislocation are able to carry it out for themselves. Less commonly great difficulty is experienced, and an anesthetic may be necessary, the use of the thumb-pressure being often insufficient.

Many mechanical devices in the way of wedges and wooden bars have been tried. I can very warmly recommend a simple method I have myself found successful—namely, the use of a pair of ordinary bifid wound-retractors. These should be sheathed with rubber tubing. An assistant, standing above the head of the patient, applies one on either side, immediately anterior to the ramus of the jaw, and makes firm pressure downward and backward, while the surgeon takes charge of the patient's chin, raising it as the pressure of the artificial fulcrum is increased.

In compound dislocation, the treatment is to be carried out on general aseptic principles. The main point to keep in mind is the possible occurrence of ankylosis, which must be combated by allowing the patient to make free use of the jaw as soon as is practicable. Should ankylosis occur on one side only, it may not require special treatment; if, however, it is bilateral, one or both joints may be excised.

After reduction, the jaw is best supported and held in position by a four-tailed bandage, so applied as to make upward and backward pressure on the prominence of the chin. This must be worn three to four

weeks. The patient should be cautioned as to the need of future care in widely opening the mouth, and fluid diet is obligatory, being best administered by a tube passed behind the last molar, if the teeth are still present.

Clavicle.—The sternoclavicular joint is peculiar in arrangement, while its relation to the movements of respiration renders it difficult to maintain the constituent bones at absolute rest. Displacement, when it occurs, is difficult to combat, on account of the weight of the depending upper extremity, the force of gravity exerting great influence on the deformity accompanying this dislocation.

The articulation owes its security to the difficulty of concentrating force directly upon it, due to the curves of the clavicle, the mobility of the scapula, and the play of the acromio-clavicular joint; also to reinforcement of the capsule by the tendinous origins of the sterno-mastoid and pectoralis major, to the costoclavicular ligament, and to the attachment of the interarticular fibrocartilage.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations, the sternal end of the clavicle was displaced in 21, or 2.58 per cent. In Krönlein's 400, the displacement occurred in 6, or 1.5 per cent.

Causation and Classification.—The accident almost invariably results from indirect violence exerted on the shoulder. It has been produced by muscular action, as in swimming; backward displacement has been caused by direct violence.

The bone may pass in either of three directions—forward, upward, or backward. Of these, the first is by far the most frequent, the second and third varieties being rare.

Forward dislocation is caused by falls or blows forcing the shoulder backward.

Pathology.—The head of the bone lies on the anterior surface of the sternum, commonly a little below its normal level, the chondrosternal cavity being crossed by the inner end of the shaft of the clavicle. The degree of displacement varies, and depends mainly on the extent of the rupture of the costoclavicular ligament.

Symptoms.—On inspection the head is found inclined to the injured side; the shoulder is approximated to the mid-line and falls somewhat backward; the hollows of the posterior triangle and the infraclavicular fossa are deepened, the former often sharply marginated anteriorly by the outer edge of the cleidomastoid. The sternal end of the displaced bone is visible as a prominence over the sternum.

Upward dislocation is caused by falls on the upper and outer aspect of the shoulder, leading to its forcible depression, or by a similar movement caused by dragging on the arm.

Pathology.—The head of the bone rests on the episternal notch, passing to or beyond the median line in front of the trachea. The inner end of the shaft lies between the sternal head of the sternomastoid and the sternohyoid, and above the chondrosternal cavity.

Symptoms.—On inspection the shoulder is found depressed, approximated to the midline of the body, and the axis of the clavicle is so shifted as to increase the distance between the sternal extremity and the first costal cartilage. The symmetry of the line corresponding with the inner margin of the sternomastoid is destroyed by the presence of the shaft of the clavicle beneath it, and the suprasternal hollow is obliterated or rendered convex by the abnormal presence of the articular end. The hollow of the posterior triangle, and also the infraclavicular fossa, are more shallow.

On palpation the sternal end of the bone may be felt, and the point of the finger may determine the outline of the joint-cavity, in the widened space between it and the first costal cartilage. The sternomastoid of the corresponding side, or both muscles are abnormally tense.

On manipulation the displaced bone may be reduced by traction of the shoulders backward, and flexion of the neck or raising of the shoulders may give rise to symptoms of tracheal compression. Pressure on the trachea may give rise to severe dyspnea, so great as hardly to allow the patient to speak.

Backward Dislocation.—In a large proportion of cases, this is caused by direct violence; but it may result from powerful lateral compression of the shoulders, and has been known to occur as the secondary result of lateral curvature of the spine.

Pathology.—The articular end lies deeply beneath the sternum and the origins of the sternohyoid. It may sometimes rise above the level of the sternum, probably as a result of

the weight of the arm depressing the outer end. The trachea is pushed over to the opposite side of the neck, the articular end of the bone resting on the gullet. The subclavian or innominate vessels may be subjected to considerable pressure. The injury to ligaments, etc., is similar in nature to that observed in the other forms of dislocation.

Symptoms.—The head is usually inclined to the opposite side, although the reverse has been noted. The margin of the sternomastoid on the sound side is abnormally prominent, the shoulder is raised and approximated to the median line, while the acromial end of the clavicle is unduly prominent. A hollow exists in the proper position of the articular end of the bone, marginated below by the sternocostal portion of the pectoralis major. On palpation, the outline of the empty cavity may be determined, and when the interarticular cartilage remains attached to the costal cartilage, this has also been felt. If the articular end of the bone rises, it may be felt above the sternum. The deformity may be corrected by drawing the shoulder backward, but reduction is seldom complete and is difficult to maintain.

Diagnosis.—The diagnosis of the different varieties is readily made by attention to the special symptoms of each already detailed. The special feature is the recurrence of the displacement when traction is discontinued.

Prognosis.—A good functional result is the rule, little permanent disability persisting. On the other hand, although easy of reduction, these displacements can rarely be kept in position, and more or less deformity remains.

Treatment.—Traction is to be made in the axis of the displaced bone, the shoulder being drawn outward and backward, some elevation being combined in the case of the upward dislocation; for the permanent correction of the deformity a pad should be placed in the axilla. Reduction is best maintained by the application of a plaster-of-Paris casing encircling both the arm and chest, either the arm being brought over the front of the chest with the hand on the opposite shoulder, or, if it proves more satisfactory, the shoulder being drawn back by a figure-of-8 bandage applied beneath the plaster. In deciding this matter we must be guided by the case before us, as considerable variation is met with in individual instances. In case of the anterior displacements, direct pressure should be applied to the head of the bone by means of a special strip of strapping and a pad. If plaster of Paris is not available, or if for any reason it is inapplicable, strips of strapping or an ordinary bandage may be employed. The displacement may be treated by placing the patient in the recumbent position after reduction, in the posterior variety the trunk being raised in such a manner as to allow the shoulder to fall backward. Great reserve should always be exercised in giving assurances to the patient as to the amount of after-deformity. The apparatus must be worn at least five or six weeks.

Scapula.—The acromion process of the scapula may be displaced from its connection with the clavicle, the accident being often described as dislocation of the acromial end of the collar bone.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations, displacement of the acromion occurred 13 times, or 1.6 per cent. In Krönlein's 400, it occurred 11 times, or 2.7 per cent. Many authorities, however, state that this dislocation is twice as frequent as that of the clavicle from the sternum.

Causation.—The displacement is rare except in adult men, and almost invariably results from the exertion of direct violence on the acromion, either by falls on or blows received by the upper and outer aspect of the shoulder. It has been observed, however, as a result of violence applied to the clavicle from below, as when the trunk is run over by a wheel. The acromion may pass in one of two directions, either beneath or above the clavicle. Of these, the latter is extremely rare.

Pathology.—The degree of displacement varies greatly, depending on the extent of injury to the coracoclavicular ligaments. If these are but slightly damaged, the clavicle rides just beyond its normal relation to the cleft, and the main injury is to the acromioclavicular capsule. When the conoid and trapezoid ligaments are both widely injured, the acromion takes up a much more internal position. Complete rupture of both conoid and trapezoid and of the coraco-acromial ligament occurs when the acromion takes up a position on the upper surface of the clavicle. The clavicle then rests between the displaced process and the upper aspect of the supraspinatus and shoulder-joint.

Symptoms.—*Subclavicular Dislocation.*—The shoulder is depressed and approximated to the median line. The acromial end of the clavicle

forms a localized prominence, marginating internally a distal depression. The axis of the clavicle is so altered as to increase its upward and outward slope, and the supraclavicular hollow is considerably deepened as a result of the tension of the clavicular insertion of the trapezius. On manipulation, the displacement is readily produced by raising the shoulder and making direct pressure on the clavicle. The individual features vary with the degree of the displacement of the acromion inward.

Dislocation Upward.—This results from force applied to the clavicle from above, and is very rare. Hamilton has pointed out that the displacement is only possible when the lower angle of the scapula is rotated outward and the coracoid process depressed, the clavicle being thus deprived of the support normally offered by the latter. The function of the upper extremity is much interfered with. On inspection the shoulder is depressed, the arm being closely approximated to the trunk and apparently elongated. The distance between the prominence of the shoulder and the mid-line is shortened. A hollow exists over the situation of the dislocation; the axis of the clavicle sinks from within outward; the sternal end projects abnormally. The cleidomastoid is very prominent. On manipulation, although voluntary movement of the shoulder is practically abrogated, all movements except those of abduction, and to a less extent of adduction, can be made passively, but with the infliction of very considerable pain.

Diagnosis.—These injuries, since they are occasioned by direct violence, are apt to be followed by rapid and much greater local swelling than dislocations of the sternal extremity of the clavicle. The only likely sources of confusion are fractures in the immediate vicinity. General rules of differentiation should here suffice, bearing in mind that in fracture the cleft is narrower, local tenderness more marked and circumscribed, while the tendency to complete recurrence of the deformity is greater in these particular dislocations than in fracture.

Prognosis.—Entire removal of the deformity is rarely attained. The most promising cases are those in which the coracoclavicular ligaments have suffered little. But if the deformity cannot be permanently reduced, the restoration of function is almost complete, free abduction being the only movement endangered.

Treatment.—The first indication is to draw the shoulder outward; and this position must be maintained by the arrangement of a pad in the axilla. The arm is then best supported and the scapula kept at rest by the application of a plaster-of-Paris case similar to that described for the clavicular dislocations. The elbow must be well brought forward, and direct pressure made over the seat of the articulation by a pad or moulded plate of gutta-percha, fixed by a strip of stout strapping carried over the shoulder and around the flexed forearm, just below the point of the olecranon.

Whatever mode of fixation is employed, it is necessary to maintain it for at least five or six weeks. The result depends mainly on the degree of injury to the ligaments; but, even if deformity persists, the functional capacity will probably be good, the movement most likely to be restricted being that of free abduction.

The lower angle of the scapula occasionally escapes from beneath the latissimus dorsi. This accident is most common as the result of paralysis of the serratus magnus or as accompanying scoliosis.

The Humerus.—The shoulder surpasses every other joint in the body in freedom of range and variety of movement. These characteristics necessitate arrangements ill adapted to withstand violence from without, which arrangements, although modified by freedom of mobility and possibilities of adaptation, yet render the joint more prone to dislocation than any other in the body.

The peculiarities which render it specially liable to displacement may be shortly summed up as follows: The prominence and exposed position of the articulation; the length of the humerus, and its consequent power as a lever when brought to bear on the capsule and surrounding structures; the slackness of the capsule, and the want of direct support of this structure at its lower and inner part; the shallowness and comparatively small surface-area of the glenoid cavity, amounting to only about one-third of that offered by the humeral head; and the fact that the movement of abduction of the humerus is normally checked mainly by tension of the capsular ligament. As compensations for these weak points we have: The abundance and strength of the tendinous insertions into the capsule, which supply a complete covering, except below; the special arrangement of the biceps tendon, which checks displacement upward in the hanging position, downward in the abducted state, as well as rotation outward in extreme supination of the forearm; the mobility of the junction of the clavicle with the acromion, which allows the glenoid cavity to be brought directly behind the head of the humerus when the arms are thrust forward; the mobility of the scapula, which renders it difficult for the humeral lever to be brought suddenly to bear on a fixed point; the fact that forced abduction of the humerus—the most dangerous movement—occurs only when the person is taken unawares; and lastly, the protection afforded to the shoulder by the overhanging shoulder-girdle.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations, 353 of the humerus occurred, forming a ratio of 43.47 per cent. of the whole number. In Krönlein's series of 400, 207 occurred, or 51.7 per cent. By general consensus of opinion, at least 50 per cent. of all dislocations take place at the shoulder-joint.

Causation and Classification.—The influence of age and sex is strongly marked in the occurrence of dislocation of the humerus. Thus it is rare below the age of twenty; and it has been shown by Krönlein that its place is taken in early childhood by fracture of the then weak clavicle, while later the still unstable elbow-joint is more likely to suffer. After twenty the proportion continues to rise steadily until old age.

The humerus may be displaced in four directions—forward, backward, downward, or upward. Of these, the first is by far the most common. The displacement in either direction may vary in degree, but the following classification covers all the main varieties:

1. Forward: Subcoracoid; Subclavicular.
2. Backward: Subacromial; Subspinous.
3. Downward: Subglenoid.
4. Upward: Supracoracoid.

Two of the rarer varieties, named from the relative position of the arm to the trunk, may be mentioned: Thus, in some cases of subglenoid dislocation, the arm is thrown upward more or less directly in the reverse of the normal (*luxatio erecta*), and in some cases of subclavicular dislocation the arm has been noted to be abducted to a right angle with the trunk (*luxatio horizontalis*, Bardenheuer).

Although the prominent position of the shoulder frequently exposes it to direct injury, dislocation is far more common as the result of indirect violence. Forcible abduction of the limb is the most frequent cause; hence the majority of dislocations are primarily subglenoid, the humerus obtaining an abnormal fulcrum, either in the acromion or in the impact of the great tuberosity with the upper part of the glenoid cavity, and bursting the lower part of the capsule. The head, as the result of the contraction of the adductor muscles and the weight of

the falling limb, travels secondarily into one of the anterior positions, most frequently the subcoracoid. When the position of the arm is the rare one of combined adduction, flexion, and internal rotation, a posterior dislocation may result; but the nature of the violence is nearer akin to the direct, as the rent of the capsule is at the posterior aspect.

Direct violence may be applied either to the head of the humerus or to its lower extremity. When applied to the head by a fall or a blow, if the shoulder is struck from above and behind, the arm being rotated outward, the head impinges on the lower and anterior portion of the capsule, and one of the anterior displacements results. When, on the other hand, the force is applied from the front with the humerus rotated inward, the upper and back part of the capsule gives way, and a subspinous dislocation is developed. A fall on the upper aspect of the shoulder may also fracture the acromion process, and the violence being continued, a subglenoid dislocation may follow. In falls upon the elbow, the mechanism is the same, forward dislocation depending on an extended and externally rotated arm, backward dislocation, on a flexed and internally rotated one. If the arm is rotated outward in the degree of extension assumed by the limb when hanging at rest, the rare supracoracoid form may result.

As to the relative frequency of the different varieties, of the 354 dislocations observed at St. Thomas's, 347 were subcoracoid or subglenoid, 4 subclavicular, and 2 subspinous. No example of supracoracoid, luxatio erecta, or luxatio horizontalis is recorded. In Krönlein's statistics, of 207 dislocations, 203 were subcoracoid or axillary, 3 luxationes erectæ, and 1 subspinous. In the St. Thomas's statistics, the subcoracoid and subglenoid are massed, on account of the different opinions as to the discrimination of these held by different observers.

Pathology.—In the *subcoracoid* variety the head of the humerus lies directly beneath the coracoid process, the tip of the latter being just internal to the bicipital groove. The great tuberosity rests on the inner and under part of the glenoid cavity, the anatomical neck on its margin, and the articular portion over the space between the glenoid cavity and the chest-wall. The short head of the biceps and the coracobrachialis cross the inner part of the head, while the remainder projects between the latissimus dorsi and the subscapularis. The long head of the biceps remains in its groove, and crosses the glenoid cavity under cover of the tense supraspinatus and infraspinatus, the capsule itself being pushed back by the head of the bone. The axillary nerves and vessels are pushed forward and inward between the subscapularis and pectoralis major, the circumflex nerve lying in the space between the subscapularis, latissimus dorsi, and humerus. These structures are seldom injured.

The rent in the capsule is either transverse or oblique, lies at the lower and inner aspect, and involves from one-half to three-fourths of the circumference; but it has been found so small as hardly to allow the passage of the head, while in very rare cases it has been entirely separated from its humeral attachment. The outer and upper part is tensely stretched over the glenoid cavity. The lower borders of the subscapularis and teres major may be somewhat torn, but the former is usually stretched over the head of the humerus. The deltoid, the supraspinatus, and the infraspinatus are tense. The last two sometimes tear off a part of the greater tuberosity. The teres minor and coracobrachialis are usually uninjured. The long head of the biceps has been found interposed between the head and glenoid cavity, completely displaced outward from its groove, or torn through.

Subclavicular.—A slight exaggeration of the last variety was named intracoracoid by Malgaigne, and considered by him the commonest of all dislocations of the humerus. The head may, however, pass still more internally and rest on the second rib and serratus magnus below the clavicle. Such dislocations are accompanied by the more severe muscular and ligamentous injuries enumerated in the last section, especially by rupture of the capsular muscles, separation of the great tuberosity, and displacement or rupture of the long tendon of the biceps, and are liable to compress the axillary vessels and nerves.

Subglenoid.—The head of the humerus rests on the upper part of the axillary border of the scapula, on the long head of the triceps, which is sometimes lacerated. The rent in the capsule is at the under part. The deltoid and capsular muscles are very tense, and both the greater and lesser tuberosities may be torn off. The circumflex nerve is sometimes torn or compressed; the axillary artery has been injured.

Subspinous.—The head of the humerus rests on the posterior margin of the glenoid

cavity, or beneath the acromion process at its junction with the spine—very rarely beneath the spine proper. The head is covered by the deltoid alone, or sometimes by the supra-spinatus also. The subscapularis, the anterior fibers of the coracobrachialis, and the short head of the biceps are much stretched; the long tendon of the biceps follows the humerus. The subscapularis may be separated, or may tear off the lesser tuberosity. The greater tuberosity also is occasionally torn off (Fig. 299).

FIGS. 299, 300.—Subspinous dislocation of the humerus (St. Thomas's Museum, London).

Symptoms.—*Subcoracoid Dislocation.*—The shoulder is depressed, the arm abducted and externally rotated. The axis of the humerus extends from above downward, backward, and outward. The infra-clavicular fossa is flattened, the anterior wall of the axilla vertically deepened, and a prominence corresponding to the position of the head of the humerus occupies its outer part. The axillary folds are slackened and the cavity shallowed. The shoulder is flattened on its posterior and outer aspect, while the acromion projects with angular outline. From the latter the deltoid descends vertically and meets the slanted humerus at an angle. The forearm is usually flexed, pronated, and supported by the opposite hand. On palpation the head can be felt in the axilla, as the arm hangs also beneath the anterior axillary wall. The acromion is readily traced, and the deltoid beneath is in a state of hollow tension over the empty glenoid cavity. On manipulation the arm is rigid, adduction is limited and only to be made by the employment of considerable force, and both adduction and flexion are very painful. On measurement little difference is to be made out, although the head of the humerus is at least $\frac{1}{8}$ inch lower than normal, the actual shortening being obscured by the obliquity of the axis of the shaft. The axillary circumference is increased by at least an inch (Fig. 301).

As already observed, the head may take up a more internal position and still be in close relationship to the coracoid process. Under these circumstances the axis of the humerus is more oblique, so that the abduction is apparently less, while the angle formed by the meeting of the deltoid and humerus is more marked. The head rests more deeply and palpably internal to the coracoid process; hence it is not so prominent anteriorly, nor can it be felt in the axilla without abducting the arm. There is internal rotation. Actual crepitus may be present, due to fracture of the great tuberosity, and the limb is more movable as a

result of the freer laceration of the capsule and other soft structures (Fig. 302).

FIG. 301.—Subcoracoid dislocation of the humerus (St. Thomas's Museum, London).

FIG. 302.—Subcoracoid dislocation of the humerus; free abduction and internal rotation of shaft due to coexistent fracture of the greater tuberosity (St. Thomas's Museum, London).

Subclavicular.—This rare dislocation is merely an increase in degree of the displacement last described. The head of the humerus travels so far inward that no abduction is apparent; in fact, a finger can with difficulty be inserted into the axilla. The axillary folds are much slackened; the head may be apparent if the pectoralis major is not highly developed or is torn, and can be felt beneath the clavicle internal to the coracoid process. Free mobility and possible crepitus are naturally still more characteristic of this variety than the last. In rare cases the arm has assumed a position of abduction at a right angle.

Subglenoid.—As already remarked, this is the initial stage of most anterior dislocations due to indirect violence, especially when the abduction is continued to hyperelevation (as in a fall through a manhole with upstretched arms), under which circumstances the arm sometimes retains its false position, the axis of the humerus coursing more or less directly upward. The forearm is then flexed, the hand either resting on the head or supported by the sound limb (*luxatio erecta*). The retention of the subglenoid position appears to depend on opposite conditions in different cases: in some, on a narrow slit in the capsule; in others, on very free laceration of the capsule and muscular insertions.

In typical cases the shoulder is much depressed and the scapula advanced. The arm is very strongly abducted, the real abduction of the humerus being greater than the apparent, since it is lessened by the rotation of the angle of the scapula toward the spine, which accompanies the depression of the shoulder. The anterior wall of the axilla is widened; there is no prominence below the coracoid process, and the hollow of the axilla is obliterated. The acromion projects strongly, and there is

much flattening of the deltoid area. On palpation, the head of the humerus is felt in the axilla, perhaps a little nearer to the anterior or posterior wall respectively. The hollow tension of the deltoid is extreme. On manipulation, the arm may be swayed a little forward or backward, but adduction is strongly opposed and extremely painful. While the arm remains abducted there may be no elongation; but when adducted in the process of reduction, lengthening may amount to as much as an inch. The axillary vessels and nerves are often compressed.

Subspinous.—As in the anterior dislocation, the degree of inward displacement varies. As a rule, however, the head of the humerus does not pass further inward than the junction of the spine and acromion process. Deformity is often not so marked as in the other dislocations, as a result of swelling of the soft parts due to the direct nature of the violence occasioning the displacement. The shoulder is much broadened externally, and a little flattened anteriorly. The arm is slightly flexed, abducted, and rotated inward; the forearm is pronated. The direction of the axis of the humerus is downward, forward, and outward. On palpation, the head can be felt beneath the junction of the spine and acromion, especially if the flexion of the arm is somewhat increased. There is hollow tension of the deltoid, and occasionally the anterior margin of the glenoid cavity can be made out. Both the acromion and coracoid processes are more readily traced than normal, if the swelling is not too great. All movements are very painful, especially attempts at supination of the forearm. The result of measurements is very variable.

Infraspinous.—In the very rare infraspinous variety the broadening of the shoulder is extreme. As in the subclavicular variety, the inward position of the head brings the arm against the trunk and obscures the real amount of abduction. Flattening between the acromion and the coracoid process is more marked, and the infraclavicular fossa is deepened and sometimes crossed by the tense short head of the biceps and coracobrachialis. The head of the humerus is readily felt below the scapular spine.

In old dislocations the abducted position is less marked, having undergone gradual correction as a result of the weight of the dependent arm. On the other hand, the disappearance of swelling and the atrophy of the deltoid give marked prominence to the acromion and coracoid processes, separated by a vertical groove anteriorly, and to the head on the dorsum of the scapula.

Supracoracoid.—In spite of its rarity, the occurrence of this dislocation has been fairly established; therefore a word must be added as to its signs.

The arm is *adducted*, slightly extended, and rotated outward. There is no flattening of the deltoid, and the head forms an anterior prominence between the acromion and coracoid processes, where its presence can be determined by palpation, and where a slight hollow beneath the acromion exists behind it, in which the posterior margin of the glenoid cavity can be sometimes felt. The coracoid process is difficult to distinguish, and may be fractured; in this case crepitus is present.

Diagnosis.—One or two points relating to the investigation of shoulder-dislocations in general may be first noticed. 1. The direc-

tion of the axis of the humerus is the cardinal indication of the position of its head; and it may be further noted that the direction of the articular surface of the head corresponds with that of the internal epicondyle. In all dislocations of the humerus except the rare supra-coracoid, the shaft of the bone is in a position of abduction, even if it be obscured by the free passage of the head on to the anterior or posterior aspect of the trunk. 2. As a result of the absence of the prominence of the head beneath the acromion, a straight edge applied to the outer aspect of the limb will rest on the acromion and external epicondyle. 3. The axillary circumference is increased when the measure is carried around at the level of the junction of the spine and acromion. 4. The position of abduction of the humerus vitiates any measurements carried from the acromion to the external epicondyle; hence, these are of little diagnostic aid.

The discrimination of the different varieties depends on careful investigation for the signs just enumerated.

The *differential diagnosis* in cases of severe contusion is to be made by the exclusion of signs of displacement, and always with the aid of an anesthetic when any doubt exists. Contusion accompanied by paresis of the deltoid may slightly simulate a dislocation when the primary swelling has disappeared. Here, however, no sign of dislocation except advancement of the head exists, and this can be generally corrected by lifting the elbow.

Certain fractures may give rise to difficulty. It must be first borne in mind that fracture of a tuberosity may accompany a dislocation. If this be the case, the variations of the typical signs of dislocation will be the addition of crepitus, possibly marked local tenderness, a tendency to recurrence, and abnormal rotation of the long axis of the shaft. Fracture of the neck of the scapula, of the neck of the humerus, or separation of the upper humeral epiphysis may be excluded by remembering that in all dislocations the head leaves its position beneath the acromion, and that the axis of the humerus is one of abduction. In all three fractures, the head is in position, the arm is adducted, and, in addition, the deformity existing is usually reduced with ease, and returns on releasing the limb. An impacted fracture of the neck may offer more trouble; but here the anterior swelling is lower, and no hollow exists beneath the acromion.

Care is sometimes necessary also in young children not to confuse a forward-hanging head in cases of infantile paralysis with palsy, or a congenital dislocation with a recent injury. In either condition the mobility of the small malplaced head, readily returning to its false position when released, together with the state of the muscular development of the limb, will be sufficient to ensure against a mistake.

Prognosis.—As to immediate reduction, these dislocations seldom prove intractable; but some difficulty is often experienced. The subclavicular variety is the most troublesome, sometimes proving irreducible, and, as a result of the extensive injury to the soft parts, often being difficult to retain in position. The latter difficulty most commonly depends on great laceration of the capsule; and it is met with also in the subspinous and, occasionally, other forms. In all varieties a tendency to ready recurrence on slight injury or incautious movement is sometimes observed.

The prognosis may be materially influenced by concurrent injuries. Of these, contiguous fracture, as of the tuberosities, will give rise to difficulty in reduction and in retaining the joint-ends in accurate position, and later the movement of the joint may be limited either as a result of inexact union, the presence of abundant callus, or non-union on the part of the fragments. Again, a fracture in the vicinity may offer serious obstacles to reduction. Injury to the axillary vessels or their branches may also be a serious complication, but fortunately it is rare. Of the nerves, the circumflex most frequently suffers, and the resulting deltoid paralysis is a most untoward event.

When unreduced, subsequent changes already dwelt upon occur in the joint, and in the absence of pressure-symptoms a fairly useful limb may be attained. The weight of the limb brings the arm to the side, and gradual increase of range of movement is obtained by exercise. The subclavicular and the supracoracoid are the most marked exceptions to this; while, as a general rule, a more useful limb is obtained in the case of the anterior than the posterior displacement, since a better new joint-cavity is developed. In the subspinous dislocations the head rests less directly on the bone, and the spine of the scapula does not offer such satisfactory support above as does the coracoid process. In other cases the persistence of the displacement is accompanied by great pain from nerve-pressure, especially in the subclavicular variety, and is followed by gradual wasting of the muscles and fixation of the joint.

Attempts at reduction are justifiable in suitable cases as late as the end of twelve months, but, as a rule, six to eight weeks may be given as the limit of the period in which they are likely to be successful.

Treatment.—If the patient comes under immediate observation, an anesthetic may often be dispensed with as unnecessary; in other cases it may be inadvisable on general grounds, the more so as anesthesia needs to be deep to be useful. If the dislocation has already existed some hours, or if the patient is nervous or of strong muscular development, anesthesia is advantageous, and often necessary.

A very large number of methods of reduction have been employed, and of these a few of the most apparent general utility will be given. It may be premised that in all methods one of the most important elements is the fixation of the scapula. The scapula may be fixed—first, by pressure on the part of an assistant over the acromion process and clavicle, the patient being either in the sitting or recumbent position; secondly, by applying a sheet carried well up to the axilla, the two ends being held by an assistant standing on the opposite side of the body; thirdly, by dragging on the opposite arm, which, by making tense the trapezius of the opposite side, provokes contraction of the muscle on the injured side; and lastly, but less efficiently, by simply placing the patient in the recumbent supine position. In all the methods of reduction, use is made of the humerus as a lever. This bone, by reason of its length and strength, is capable of exerting great power; and in this respect it is well to bear in mind that in some of the so-called manipulative methods, the leverage exerted is so great as to effect, if injudiciously used, more serious local injury than those methods of extension that are generally regarded as more violent in their nature.

Methods.—1. Abduction of the arm with direct digital pressure on the head from the axilla, combined, if necessary, with moderate traction and rotatory movements. Rotation should first be made in an external direction, and be followed by internal rotation and adduction. This method is well adapted for the reduction of subcoracoid dislocations in weakly developed persons and in the young.

2. The same procedure, but with increase of the movement of abduction to hyperelevation, the scapula being fixed. This is especially suitable to some cases of subglenoid dislocation, particularly those with slight abduction of the arm.

3. *Manipulation by Kocher's Method.*—The patient is best recumbent, but the maneuvers can be carried out in the sitting position.
First Stage.—An assistant stands behind and fixes the scapula by pressure on one or, better, both acromion processes. The surgeon grasps the patient's forearm above the wrist with one hand, and the arm

FIG. 303.—Position preparatory to making traction and direct pressure.

at the elbow with the other; the abducted limb is then carried against the trunk and pressed firmly down. This corrects the direction of the axis of the humerus and puts the upper and outer part of the capsule on the stretch (Fig. 304).

FIG. 304.—Correction of abduction.

Second Stage.—The arm being held firmly to the trunk, the forearm is carried by external rotation of the humerus nearly into the frontal plane of the trunk. This utilizes the tension of the intact part of the capsule in bringing the head outward, and causes the rent to gape; it also disengages the groove on the anatomical neck from its position on the margin of the glenoid cavity (Fig. 305).

Third Stage.—The arm is carried across the body in the frontal plane and internally rotated. This brings the cartilage-clad portion of the head opposite the gap in the capsule; and the head should now enter the glenoid cavity (Fig. 306). It will be observed that the stage in which the greatest care is necessary not to employ excessive force is that in which external rotation is made. The method is applicable to all anterior dislocations; but in the case of the subclavicular it must

FIG. 305.—Adduction and external rotation.

be preceded by traction to draw the head outward, practically into a subcoracoid position.

4. *Manual Extension with the Heel in the Axilla.*—The patient reclines, while the scapula is fixed by a towel passed over the acromion and held by an assistant on the other side. The surgeon seats himself on the edge of the couch, places the unshod foot in the axilla of the patient, and, grasping the forearm just above the wrist, makes steady traction, at first in the axis of the displaced bone, gradually bringing the limb around the fulcrum offered by the heel inward. This opens the slit in the capsule at the same time that the head is carried outward;

FIG. 306.—Adduction, flexion, and internal rotation.

and the head is usually drawn by the muscles into position. A movement of rotation at the termination of the maneuver may be useful. This method can be carried out without assistance, and is very generally useful. At the same time it must be borne in mind that the heel

in the axilla has been responsible for many of the complications seen in the reduction of shoulder-dislocations, particularly injuries to the vessels.

5. *Extension with the Knee in the Axilla.*—The patient sits, the surgeon standing behind him and placing his foot on the stool. Traction is then made by an assistant, the surgeon manipulating the head with one hand, while direct downward pressure is made on the acromion with the other.

6. *Hyperextension.*—This is not a good method for general application, as it is liable to cause considerable laceration of the soft structures. It may be applied by placing the patient in the recumbent position. The surgeon stands at the head of the couch, and grasps the limb with both hands; then, placing the hollow of the foot on the acromion process, he makes extension, which is carried to a needful degree of hyperelevation. Another method is the so-called "*pendulum method*," in which the patient lies on the floor on the uninjured side. The injured arm is then grasped and traction made, the weight of the body serving as counterextension.

Any of these purely manual methods may be combined with traction by pulleys; or in very obstinate or old cases the whole method may be varied, pulleys being employed for purposes of extension, while counterextension is obtained by one towel carried around the axilla and another around the body to fix the scapula. The directions given as to ancillary movements of manipulation, of course, apply equally here.

Posterior displacements are best treated by one of the extension methods.

After reduction, a small pad should be placed in the axilla, the forearm flexed, and the arm firmly bandaged to the side. At the end of a week a sling may be substituted for the bandage, and slight movements cautiously made. These may be increased during the next few weeks, and combined with warm bathing and massage. It must always be remembered that, on the one hand, these dislocations are liable to be readily followed by stiffness and atrophy of muscles, if not treated with sufficient care as to movement; while, on the other hand, too free movements tend to the development of a widened capsule—so often a source of permanent weakness and tendency to recurrence. Immediate recurrence or recurrence during the first days is rare. It depends either on careless movements of the patient, the limb being insecurely fixed, on great laceration of the tissues, detachment of the tuberosities, or possibly on the collection of a large amount of synovial and sanguineous effusion.

In a small proportion of cases a dislocation is followed by the acquisition of so marked a tendency to recurrence that displacement becomes habitual on the slightest uncontrolled movement of abduction. For this condition the treatment is strict limitation of movement by the constant use of suitable braces, or an incision with shortening of the capsule by excision of the stretched portion.

Compound and Complicated Dislocations.—The former are extremely rare. As a rule, they demand conservative treatment only; but a limited excision may be useful to facilitate reduction and ensure future drainage.

The question of complication by fracture of the shaft of the bone has been already alluded. Mention should be made of McBurney's method of exposing the lower end of the upper fragment and inserting a hook into it, by which traction was made and the dislocation successfully reduced.

If the axillary artery or vein has been injured and a diffuse traumatic aneurysm has developed, the only treatment is free opening up of the axilla by division of the pectoral muscles, rapid clearance of the

clot, and search for the bleeding point, the third part of the subclavian being meanwhile compressed. The success of this formidable operation depends entirely on freedom of incision and rapidity of procedure. When the axilla is opened up, direct pressure on the axillary vessels may take the place of the less efficient proximal compression of the subclavian.

Old Dislocations.—The same methods of reduction are available; but we must bear in mind the changes which have occurred, such as the formation of adhesions, particularly of the capsule to the glenoid cavity, the shortening of some parts of the capsule and surrounding structures and the corresponding lengthening of others, and even the thickening and loss of contour of the bone-surfaces. Any method of reduction must be preceded by free passive movements in all directions, to break down adventitious adhesions. Kocher's manipulations may then be tried, followed by extension methods if necessary; but the external rotation in Kocher's method must be cautiously employed, to avoid fracture of the humerus from torsion, which has several times occurred. Efforts have been successful up to nine and even twenty-one months, but, as a general rule, six months is the latest hopeful limit.

In deciding on a trial, several points must be fully considered; and these are not the less to be kept in mind in the carrying out of the necessary manipulations, some cases naturally allowing of a much more forcible treatment than others. These points may be grouped shortly as follows: 1. The degree of usefulness of the limb; 2. The age and occupation of the patient; 3. The condition of the blood-vessels; 4. The existence of evidence of nerve-pressure; 5. The degree of previous inflammation which may have existed; 6. Whether the original injury was complicated by fracture.

Loss of function and pain are the most pressing indications for interference, and under these circumstances any of the above methods may be inadequate, and an operative method may be demanded. Subcutaneous incision may be passed over with a word, as seldom likely to be of definite use; but, occasionally, persistent deformity and pressure-symptoms may be relieved by altering the axis of the limb by means of subcutaneous osteotomy. Open incision and reposition are suitable to some cases in which the dislocation is of short standing; and it may be combined with pegging or suture of the great tuberosity, if this is loose and leads to difficulty in keeping the bones in apposition. Excision of the joint has proved very successful in cases in which nerve-pressure and deficiency in movement are prominent features. No more than the articular portion of the head needs removal in the majority of instances. In deciding to adopt this treatment, the temperament of the patient needs especially careful consideration, since no good result will be obtained unless sufficient capacity exists for the endurance of a considerable amount of suffering in the after-treatment by passive exercise.

Lastly must be enumerated the accidents which have happened during trials at reduction of dislocations of the shoulder. They are placed here because it is in old dislocations that the majority of them have occurred. These are shortly: 1. Severe contusion of the soft parts, perhaps followed by cellulitis; 2. Great subcutaneous laceration of the capsule and muscles; 3. Laceration of the blood-vessels, espe-

cially the tearing of one of the lateral branches of the axillary artery by the heel in the axilla; 4. Injury to the nerves of the brachial plexus; 5. Fracture of the humerus, or ribs; 6. Avulsion of the limb.

Radius and Ulna.—The elbow-joint offers the most complicated bony surfaces for contact of any articulation in the body, while bony apophyses, projecting on either side, give increased power and range of action to the muscles which act upon it.

Its stability depends on the depth of the sigmoid cavity of the ulna, the more important of the two bones of the forearm taking part in the articulation; it depends also upon the great strength of its lateral ligaments, and the support given by the triceps behind, the brachialis anticus in front, and the flexor and extensor muscles of the forearm on either side. The special characteristics of dislocations of the elbow-joint depend on the number of separate prominences offered by the bones, and on the fact that the movements of the joint are for the most part limited by actual bony contact of some one of these processes on the corresponding cavity of reception. The presence of a number of bony prominences accounts for the frequency with which these dislocations are accompanied by fracture, while the processes often form the abnormal fulcrum by which the bones are levered out from their proper relationship.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations, 158 of the elbow occurred, forming a ratio of 19.45 per cent. of the whole number. In Krönlein's series of 400, 109 occurred, or 27.2 per cent. The dislocation therefore stands second in order of relative frequency.

Causation and Classification.—In no other joint is the influence of sex and age so intimately connected with the concurrence of dislocation as in the elbow. Thus, in our table of 158 dislocations, 136 were in males, and only 22 in females; in 7 the age was unstated, but of the remainder, 41 occurred between the ages of five and ten, 79 between the ages of ten and twenty, leaving only 31 to be distributed in steadily increasing infrequency over the next four decades.

In children the shallowness of the cavities of reception and the corresponding want of prominence of the processes allow dislocation to occur more readily (Bardenheuer). Again, the mode of development of the lower humeral epiphysis predisposes to dislocation by offering special opportunities for epiphyseal separation, the centers of ossification being multiple. Considering the frequency with which separation of one of the condyles occurs with dislocation, this is a point of much importance. It must, however, be borne in mind that separation of the lower epiphysis, as a whole, often saves the elbow-joint from injury.

The great majority of the dislocations are due to indirect violence, and result from falls on the extended pronated hand spread out to save the trunk from sudden impact with the ground. With a fully extended forearm the elbow-joint usually escapes injury; but if a slight degree of flexion exists, dislocation often occurs, and most frequently in a backward direction. The latter may be further influenced by abduction and rotation of the arm due to the continuing movement of the trunk either forward or backward as it travels to the ground, while the hand remains a fixed point. More rarely, violent abduction or adduction gives rise to rupture of the external or internal lateral ligaments, or to separation of the corresponding epicondyles, with consequent displacement of the bones of the forearm in the opposite direction to the lateral rupture. Again, dislocation may result from hyperextension or forcible rotation, the latter especially in machinery accidents. Direct violence applied to the olecranon process or to the inner side of the flexed forearm may give rise to displacement forward or outward respectively.

The bones of the forearm may pass in either of the four angular directions—backward, forward, outward, or inward. Of these, backward is by far the most common. The rarity of the inward displacements is readily explained by the great prominence of the inner edge of the trochlear groove and the projection of the inner epicondyle.

Except in the case of the backward variety, complete dislocation of the bones is rare. Of our 158 cases, the direction is reported as follows: Backward, 81; back and out, 39; outward, 16; back and in, 3; divergent, 3; double, 1.

Pathology.—The injury to the bones and soft parts is briefly as follows in the different varieties:

Backward Dislocation.—The coronoid process rests in the olecranon fossa, the radial head behind the capitellum. The internal epicondyle may be separated, or more rarely the coronoid process fractured. The anterior part of the capsule is completely torn, also the anterior parts of the lateral ligaments, especially the inner. The orbicular ligament is unhurt, and the posterior part of the capsule often escapes injury also, while the anterior torn portion may be interposed between the displaced bones. Of the muscles, the brachialis anticus suffers most. This is tense, and often is severely lacerated. The biceps is less tense. The brachial artery is compressed. The median and musculospiral nerves are stretched. The ulnar usually escapes injury, probably as the result of lateral displacement. The skin of the crease of the elbow sometimes gives way when the accident results from forcible hyperextension. The displacement is occasionally less complete, when the coronoid process rests against the trochlea instead of occupying the olecranon fossa.

Forward Dislocation.—The end of the olecranon rests on the front of the trochlea, and, contrary to the opinion at one time held, is rarely fractured and left behind. The rent in the capsule is very extensive, both anterior and posterior aspects being much torn. The internal lateral ligament is much damaged, the external less so. Fracture of one of the processes of the ulna or one of the epicondyles is common.

Lateral Dislocations.—The injury in these cases resembles that described for the other varieties, with the difference that the corresponding lateral ligament suffers more completely. In the outer variety there is often much injury to bony processes, and the ulnar nerve, or less often the posterior interosseous nerve, is stretched or torn. The sigmoid cavity rarely passes beyond the capitellum.

Divergent Dislocation.—In this variety the articular end of the ulna passes backward, and usually is a little rotated inward. The head of the radius lies in front of the humerus also, somewhat internal to its proper position, as well as too high. The main feature in the injury to the soft parts is the complete rupture of all the ligaments, including even the orbicular. In Pitha's case the coronoid process was separated, and the brachialis and biceps were torn from their insertions.

The frequency of co-existing fracture has no doubt been much underrated. In the St. Thomas's series 26 fractures are noted thus: Internal condyle, 18; external condyle, 3; coronoid process, 1; separation of lower humeral epiphysis, 1; fracture of radius, 1; fracture of ulna, 1. These amount to 26, or 16.45 per cent. of the whole number; but in all probability many cases were overlooked.

Symptoms.—In *backward dislocation* the elbow is slightly flexed, usually forming an angle of 135 degrees. The flexion is accompanied

FIG. 307.—Backward and outward dislocation from behind (St. Thomas's Museum, London).

by some abduction in the majority of cases, due to the fact that the displacement is in part the result of forced abduction, and hence not directly backward. Tension of the pronator teres also commonly produces some pronation; but the forearm may be supine. The long

axes of the arm and forearm cross each other; the forearm is shortened, while the diameter of the arm above the elbow is increased. The elbow-crease is pushed down and prominent, the olecranon and internal epicondyles are prominent, and the tense triceps is sometimes visible stretching up from the former process. On palpation the olecranon is prominent and projects behind and above the internal epicondyle. The cup-shaped radial head may be felt posteriorly, and it is absent from its normal position beneath the external epicondyle. If the swelling is not great, the articular surface of the humerus may be traced in the bulging elbow-crease. On manipulation all movements are painful, and are made in an abnormal axis. Pronation and supination and flexion to a right angle may be made; but practically no extension is possible. Abnormal lateral mobility may exist.

Forward Dislocation.—This displacement is very rare, and its occurrence without coexisting fracture of the olecranon has been doubted. In point of fact, however, the latter complication has been still more rarely recorded. On inspection the forearm is usually found flexed to an acute angle, but it has been seen extended. The actual length of the arm is decreased, and the vertical diameter of the forearm increased. The epicondyles are prominent. In the absence of the olecranon, the outline of the posterior surface of the humerus may be traced on palpation. Anteriorly, the coronoid process, and even the sigmoid cavity, may be felt. On manipulation, the forearm may be somewhat extended, but the amount of flexion existing cannot be increased.

Outward Dislocation.—The forearm is slightly flexed, the radius usually strongly pronated, as the head generally fails to maintain its outward position and passes forward. In the exceptional instances in which the radius projects outward, the forearm may be supine. The whole joint is broadened, and if the radius is much rotated, the vertical diameter of the forearm is increased also. When the limb hangs by the side, the forearm is seen to be markedly abducted. The internal epicondyle is very prominent. If, as is commonly the case, the outward displacement is combined with a backward one, the olecranon and the triceps tendon are prominent, and also abnormally widely separated from the internal epicondyle.

On palpation the signs will differ with the degree of external displacement and as to whether it is combined with a backward one. In the pure outward cases the sigmoid cavity usually embraces the capitellum. The radial head is then to be felt a little anterior and external to the outer epicondyle, while internally and behind, the internal epicondyle and olecranon fossa may be traced, and the point of the olecranon is removed from its normal proximity and relation to the former. The biceps tendon is displaced inward, and is tense and prominent. If the inner condyle should have been separated, it may lie in either the olecranon or coronoid fossa, and the trochlea will take its place as the most internal landmark. On manipulation rigidity of the flexed joint is a marked feature. There may be symptoms pointing to injury to the ulnar nerve, which is particularly exposed to pressure, stretching, or laceration in a displacement of this variety.

Dislocation Inward.—The elbow is slightly flexed and markedly pronated. As the limb hangs by the side, adduction is sufficient to

reverse the normal angle of the elbow, the angle being salient outward, and the external epicondyle prominent. On palpation the olecranon rests beneath the internal epicondyle and obscures it; the outer epicondyle is prominent, and the capitellum is to be felt. The head of the radius must be searched for anterior to the trochlea. The distance between the olecranon and the external epicondyle is much increased; the latter may be separated. Complete dislocation of the bones inward does not occur, but inward displacement may be combined with a backward one.

Divergent Dislocation (Ulna Backward; Radius Forward).—The forearm is slightly flexed, and rests midway between pronation and supination. The elbow-crease is obliterated, and filled by a prominence due to the position of the head of the radius. The vertical diameter of the forearm is increased, the lateral not. The whole limb is shortened; but upon measurement the individual segments are found to be of normal length. The shortening may amount to from 1 to 3 inches. On palpation the condyles are abnormally prominent, and parts of the articular end of the humerus may be felt on each side. The olecranon is above its normal level, but often approximated to the inner condyle. On manipulation, the limb is very rigid, any flexion particularly being opposed by the head of the radius. Less pronation and supination are possible than in any other variety.

Diagnosis of Dislocations of the Elbow.—A determination of the particular variety of dislocation can be made only by a careful

FIG. 308.—Backward dislocation of radius and ulna (skiagraph by Stanley F. Kent and Edwin White).

consideration of the distinctive features of each as above detailed; but it must be borne in mind that the various signs on inspection and palpation are often much obscured by surrounding swelling of the soft parts, especially when the displacement is the result of direct violence. The most important point is the careful comparison of the relation of the bony prominences around the articulation, both on the sound and on the injured side. The special difficulty in these dislocations arises from their frequent association with fractures, especially of the epicondyles of the humerus. The presence of a fracture is evidenced by the ordinary signs of abnormal mobility

—crepitus and fixed local pain; but these signs may coexist with evident signs of dislocation, such as interference with the general mobility of the joint, and a general disturbance of the normal relationship of the bony landmarks.

One of the most common sources of confusion is a separation of the combined lower epiphysis of the humerus. To distinguish this from a posterior dislocation of the radius and ulna, it suffices to keep the following points in mind: (*a*) The relative position of the olecranon and condyles is unchanged; (*b*) the arm is shortened; (*c*) movement causes much pain, is abnormally free, is accompanied by crepitus; and (*d*) reduction of the deformity is followed by recurrence when traction is discontinued. Again, the anterior prominence in the case of fracture is above the level of the elbow-crease, and is very tender on pressure. Lastly, it is important to decide in some instances whether a dislocation is a recent or an old one. A careful attention to the history is here of the first importance. The elbow is the joint, however, in which the employment of the *X*-rays is especially likely to be of decided utility (Fig. 308).

Prognosis.—With regard to the question of immediate reduction, the prognosis in dislocation of the elbow may be said to be especially good, all forms giving little trouble. As the complete outward and the divergent forms are accompanied by extensive rupture of the ligaments, they are the most likely to leave a certain want of security behind them. The most important factor in the prognosis is the coexistence of fracture, which often leads to deformity, limitation of movement, or even complete ankylosis, as the result of inexact healing of the fragments or the formation of superabundant callus. Again, the inclusion of either the ulnar, posterior interosseous, or rarely the median nerve in such callus may lead to a bad functional result.

FIG. 309.—Reduction of dislocation of the elbow by Cooper's method.

Treatment.—The best general method of reduction is that of Cooper. The patient and surgeon place themselves in the position indicated in Fig. 309. In the posterior dislocations both hands may be applied to the forearm for purposes of traction; when lateral deviations exist, the second hand or the hands of an assistant may be necessary to make direct pressure on the lateral aspects of the joint. The knee is so placed in the flexure of the elbow as to support the humerus and at the same time to press firmly against the forearm to disengage the coronoid process. Traction followed by flexion is then made in the axis of the forearm, and the bones usually slip into position with a sensation of false crepitation or a distinct snap.

In posterior displacements, if difficulty occurs, the joint may be hyperextended so as to disengage the coronoid process and dilate the rent in the capsule. The elbow is then flexed under traction.

Forward displacement is best treated by Cooper's method, firm pressure being made with the knee against the forearm; or the elbow may be flexed by an assistant, who with one hand makes traction in such a direction at the upper end of the forearm as to disengage the olecranon from the front of the humerus, while with the second hand the patient's hand is approximated to the shoulder. The surgeon meanwhile first fixes the humerus, and then attempts to guide its progress forward.

In the lateral deviations reduction is often facilitated by adducting the arm in inward displacements, or abducting it in outward ones —*i. e.*, by repeating the movement which has originally given rise to the dislocation, and thus dilating the lateral rent in the capsule.

In the divergent variety traction in the axis of the displaced bones, followed by flexion and supination for the reduction of the radius, is the most reasonable method, or the two bones may be reduced individually.

After reduction the flexed elbow should be put up in a plaster-of-Paris bandage or on an angular splint, and kept at rest for at least two weeks. The splint should then be removed for exercise and massage, and may be replaced by a lighter and easily movable appliance. When the dislocation is accompanied by fracture, especial care is necessary to prevent ankylosis; and here the general rule to be observed in fractured condyles is applied—namely, to commence movement cautiously as soon as sufficient callus has been formed to unite the fragments.

Old Dislocations.—Attempts should be made to reduce these at any rate up to the end of six months, although reduction is always extremely difficult after the lapse of six weeks.

The difficulty in uncomplicated cases depends on the extremely complex surface offered by the bones of the articulation; and naturally those cases are the most difficult and unpromising in which the proper conformation has been distorted by fracture of one or more of the processes. Subcutaneous tenotomy and division of bands are practically useless, but open incision and the removal of large masses of callus or badly united fragments may greatly improve the functional capacity. In other cases, especially where there is deformity, a partial excision is indicated. The triceps should be separated with the olecranon and both turned up; and the radio-ulnar joint should always be spared if possible. The olecranon should be subsequently wired. Removal of bone, especially of the humerus, needs to be very free in cases of abundant callus-formation.

Compound Dislocation.—When the wound is small or a mere puncture by the bone, pure conservatism and asepticity are indicated. If severe and contused, a partial excision with the view of providing efficient drainage may give a better chance of a movable joint. Amputation is indicated only in advanced age, general constitutional defects, or extreme local destruction.

Isolated Dislocation of the Ulna.—Either extremity of the

ulna may be dislocated. These accidents are, however, very rare, and, as would be expected, especially that affecting the upper end. A large proportion of the cases are, no doubt, really incomplete dislocations of the elbow.

Upper Extremity.—The displacement of the ulna is necessarily backward, or backward and somewhat inward; and for its production violence must be exerted directly on the upper part of the shaft from before. To allow the dislocation, the internal lateral and the inner part of the posterior or anterior and posterior ligaments of the elbow must be torn. If the displacement is at all great, the orbicular ligament also must be detached, or the external lateral ligament must be torn or set free by fracture of the external epicondyle.

Symptoms.—The forearm is either slightly flexed or extended—adducted—at least to a degree destroying the normal saliency of the inward angle of the junction of the arm and forearm, and very markedly pronated to allow of as great approximation as possible of the carpus to the trochlea. The inner margin of the forearm is shortened and thickened. The olecranon is prominent, and stretching up from it is the tense triceps tendon. On palpation the olecranon is found to be higher than normal, often approximated to the internal condyle laterally. The inner condyle is obscured by the adduction of the forearm; the external is prominent, and the head of the radius is felt below it. It may be possible to feel the uncovered trochlea in the elbow-crease.

Treatment.—The displacement may be reduced in the manner already described in the case of the elbow, traction and extension being combined with abduction of the forearm. The after-treatment is identical.

Lower Extremity.—This dislocation is commonly combined with fracture of the radius, but it also occurs as an uncomplicated condition. The ulna may be displaced on to either the dorsal or the palmar aspect of the radius. The dislocation is usually the result of direct force exerted on the ulna, the radius being fixed and the hand extended. Dorsal displacement may also be produced by forced pronation of the flexed wrist—palmar by forced supination, the wrist being extended. The triangular fibrocartilage is separated; the anterior and posterior inferior radio-ulnar and the internal lateral ligaments of the wrist are torn.

Symptoms.—In dorsal displacement the hand is moderately adducted, and about midway between pronation and supination, occasionally inclining to one or other of the latter positions. The width of the wrist is decreased, while the thickness is increased, especially at the ulnar side. The axis of the ulna, if prolonged, would be continued to the middle finger. On palpation the styloid process is absent from its position; the head of the ulna may lie on the radius or even on the semilunar bone. On manipulation, supination is impossible, and flexion and extension are very painful.

In palmar dislocation the hand is either strongly supinated or in the mid-position between pronation and supination. On palpation the head is felt anteriorly, and there is a hollow posteriorly over the cuneiform bone. Either of these dislocations may be compound.

Treatment.—To reduce the dislocation the radius must be fixed between one finger and thumb, and direct pressure made with the

other thumb on the head of the ulna; then, in the case of the dorsal displacement, the hand should be supinated; in the palmar, pronated. The limb should be fixed on a splint in the supine position if the dislocation has been dorsal, or the reverse if palmar. The lower end of the ulna is occasionally rendered abnormally mobile by a similar accident to that producing a Colles fracture, but without any antero-posterior shifting.

Isolated Dislocation of the Radius.—The isolated displacement of the head of the radius is far more easy to comprehend than that of the ulna, still the majority of instances are properly regarded as incomplete dislocations of the elbow.

Frequency of Occurrence.—In the St. Thomas's series of 812 dislocations of all joints, 30 of the radiohumeral occurred, or a ratio of 3.69 per cent. In Krönlein's series of 400, 15 occurred, or 3.77 per cent.

Causation.—The anterior and posterior displacements may both be occasioned by direct violence applied to the aspect of the forearm opposite that on which the head escapes, or, in the case of the posterior dislocation, by force applied to the back of the humerus, the elbow being in a position of flexion. The larger number of cases, however, are the result of indirect violence, such as falls on the hand and traction on the extended supinated forearm, the latter especially in children. The forward dislocation is sometimes due to muscular action, as has been observed in the action of the biceps in lifting a heavy weight, or in forcible movements of supination, as in wringing out clothes.

The head of the radius may be displaced in three directions—viz., forward, by far the most common; backward; or outward, the least common.

Symptoms.—Certain signs are common to all three varieties and their degrees: 1. Shortening and vertical increase of diameter of the radial margin of the forearm; 2. Abduction of the forearm; 3. Consequent elevation of the styloid process of the radius; 4. Alteration of the axis of the radius; 5. Absence of the head of the bone in its normal position beneath the external condyle; 6. A certain degree of lateral mobility at the elbow.

Forward dislocation may be complete or incomplete. On inspection the elbow is found one-quarter flexed, more or less pronated and abducted. The common origin of the extensor muscles of the forearm is pushed outward, and the head of the radius may be visible, as well as the external condyle, in spite of the abduction. The internal epicondyle is abnormally prominent, the hand is abducted, and the axis of the radius strikes the anterior surface of the humerus (Figs. 310 and 311). On palpation, if the elbow is neither fat nor swollen, the head of the radius can be felt anterior to the external condyle of the humerus, covered by the tense biceps tendon and fascia. At the bottom of the hollow in the normal position of the head, the ulna, the lesser sigmoid cavity, and the under and posterior part of the capitellum may be felt. On manipulation the elbow can neither be flexed nor extended; in the former movement the head of the radius strikes against the front of the humerus. Pronation and supination are very

limited. There is some abnormal lateral mobility. Paralysis occasionally results from injury to the posterior interosseous nerve.

In *backward dislocation*, the elbow is slightly flexed, and stands midway between pronation and supination. On palpation the head can be felt behind and above the external epicondyle; the latter can be

FIG. 310.—Old forward dislocation of head of the radius.

mapped out as to its outer and anterior aspects, and below it a hollow is to be determined. The tense biceps tendon may be distinguished in the inner part of the hollow. On manipulation, no extension is pos-

FIG. 311.—Forward dislocation of head of the radius, showing crossing of axis of the bones (skiagraph by A. B. Blacker).

sible, and little flexion. Pronation and supination are also practically abrogated, especially the latter.

In *outward dislocation*, the elbow is moderately flexed and the forearm pronated. On palpation the head is to be felt above and to the outer side of the external epicondyle. On manipulation, flexion and

extension are painful and difficult, but less limited than in the other varieties. Supination is interfered with. When there is coexisting fracture of the upper third of the ulna, the whole forearm is shortened, and mobility is naturally greater.

Diagnosis.—A differential diagnosis is readily made by attention to the points above enumerated. It must be borne in mind, however, that the displacements, both forward and backward, are occasionally incomplete, and under these circumstances the signs, though of the same nature, are less strongly marked. In the forward dislocation the impossibility of complete flexion is the most valuable diagnostic aid.

Treatment.—*Forward Dislocation.*—The forearm should be flexed to relax the biceps and pronator radii teres, the forearm adducted to lower the head, and then extended and supinated, firm direct pressure being made at the same time on the displaced head. If this maneuver fail, hyperextension combined with adduction and direct pressure may be tried. The limb is best put up either very fully flexed in plaster of Paris, or extended, with a pad over the head of the radius.

In *posterior dislocation*, traction is made on the extended supinated forearm, followed by pronation, and accompanied by direct pressure and abduction. The limb should then be put in a position of flexion.

In *outward dislocation*, extension, abduction, and supination are made, with direct pressure downward and inward. The limb is put up in a flexed position.

When efforts fail to reduce one of these dislocations, the joint may be opened and an attempt at reposition made. This is often by no means easy, and then has failed to effect permanent retention. For this reason a temporary suture passed through the head and the capitellum and retained for fourteen days has been employed with success by Bardenheuer. Should the reposition of the head prove impossible, it should be resected, but great care will still be needed to ensure a movable joint.

Subluxation of the Head of the Radius.—In early childhood a condition to which the above name is applied results from forcible dragging on the forearm, often by the nurse, or in play. It is probably explained by the normal laxity of the orbicular ligament in children, already referred to, and to want of full development of the head of the radius. It has been ascribed to a slight displacement downward of the head of the radius together with the formation of a fold of the ligaments, which becomes interposed between the back of the head and the capitellum. In connection with this theory, the normal projection of the synovial and subsynovial tissue as a ring, resembling an incomplete meniscus, around the head of the radius may be mentioned, since swelling of this segment of the synovial capsule might produce an identical condition. J. Hutchinson, Jr., considers the deformity due to the head of the radius slipping out of the grasp of the orbicular ligament. Fracture of the neck of the radius has proved the explanation of a corresponding deformity in some cases; displacement of the inferior radio-ulnar fibrocartilage also produces similar signs.

The forearm is held flexed in a prone position, or midway between a prone and supine position. Supination is very painful. The signs may be removed by complete supination followed by flexion, under an anesthetic if necessary. The forearm should then be placed in a sling, and massage and careful exercise employed.

Carpus.—The articulation of the wrist owes its security to the fact that it is surrounded by a large number of tendons, and that these in addition are held in close and firm relationship with it by the so-called annular ligaments.

Anteriorly and posteriorly there is no bony prominence beyond that provided by the slight concavity of the lower end of the radius; and as to the capsule, the posterior aspect is decidedly the weaker. Laterally the influence of tendons is less marked; but here beyond the strong lateral ligaments we have the projecting styloid processes. The articulation is essentially one between the carpus and radius; hence we find all the provisions are directed to the maintenance of these two elements in contact. Thus, the styloid process of the radius projects lower; the direction of the fibers of both the anterior and posterior ligaments is from the radius downward and inward. In full flexion, and especially extension, the hand is drawn to the radial side, so that the fingers are adducted; and adduction is a free movement limited by tension of the soft structures only, while abduction which would throw the carpus against the small lower end of the ulna is strictly limited by the bony contact of the styloid process of the radius with the scaphoid bone.

Frequency of Occurrence.—Luxations of the wrist are extremely rare. Thus, in the largest collection of cases which was compiled from general literature by Parker in 1871, only 33 were included; and in Krönlein's statistics we find only 1 example. In the St. Thomas's series, however, dislocation of the wrist is said to have occurred 8 times among 812 dislocations of all joints, a ratio of .98 per cent.

Causation.—The rarity of the injury is no doubt accounted for by the shortness of the lever formed by the hand, and the greater frequency of fracture of the radius. It is ordinarily the result of indirect violence, most commonly a fall on the outstretched palm, in a position of full pronation and extension, which therefore causes also some deflection to the ulnar side. The hand becomes the fixed point, and the bones of the forearm press down to the ground, so that the carpus is displaced on to their dorsal aspect. The opposite displacement may be produced by a fall on the flexed wrist. Anterior dislocation has been observed as a result of hyperextension. Occasionally the accident is due to direct violence. The dorsal and palmar are the only two recognized uncomplicated dislocations, and of these the dorsal is twice as frequent as the palmar.

Pathology.—The anterior and posterior ligaments are usually extensively torn; the external lateral also is usually torn through, or the radial styloid process separated. The internal lateral ligament often escapes. The radial styloid process is the one most often injured. In the dorsal dislocation the extensor tendons are lifted from their grooves, carrying with them the attachments of the annular ligament to the bone; and they are displaced more or less to the radial and ulnar sides.

Symptoms.—In *backward dislocation* the elbow is flexed, the forearm in a position midway between pronation and supination. The wrist itself takes up no definite position, but may be deflected in either of the four angular directions. The fingers are flexed at the metacarpophalangeal joints, and the interphalangeal joints are extended. A steep, transverse, dorsal prominence exists, and on the palmar aspect a less marked palmar projection, reaching well down to the base of the thumb. The long axis of the hand crosses that of the forearm. On palpation the styloid processes bear their normal relationship to each other, are in the axis of the forearm, and before the convex dorsal prominence of the carpus. The articular surface of the radius is obscured anteriorly by the flexor tendons, which dip sharply back-

ward to pass beneath the annular ligament. On manipulation, all movements are interfered with. Measurement shows: (*a*) the length of the radius from its head to the tip of the styloid process to be equal to that of the opposite limb; (*b*) the distance from the upper margin of the dorsal prominence to the tip of the middle finger to equal that from the line of the radiocarpal joint to the same point.

In *forward dislocation*, the dorsal prominence is concave from side to side, and in a recent injury the styloid processes are visible. The palmar prominence is convex upward, and somewhat obscured by the thickness of the flexor tendons. On palpation and measurement, the signs resemble those already detailed in the case of the dorsal displacement, except in regard to the reversal of the top level of the prominences (the palmar being the higher), the concave outline of the dorsal prominence, and the possibility of tracing the outline of the radio-ulnar arch.

Diagnosis.—If the points above detailed under the heading of Symptoms be borne in mind, no difficulty should occur in the verification of this injury. Colles's fracture and separation of the lower radial epiphysis are the only stumbling-blocks; and confusion with either of these is readily avoided by attention to the relative position of the bony landmarks.

Prognosis.—Reduction is easy, and, in spite of the shallowness of the joint-cavity, no marked disposition to recurrence has been observed.

Treatment.—The displacement is readily reduced by traction in the axis of the displaced hand, combined with direct pressure on the dorsal or palmar prominence, as the case may be. The hand and forearm should then be placed on anterior and posterior splints, well padded opposite the position of the late carpal prominence, the fingers being allowed to project, so as to guard against subsequent stiffness from fixation of the tendons. After fourteen days the splint should be removed daily, the hand and forearm massaged, and careful movement of the fingers carried out. The splints should be retained for four to five weeks, and in many cases may be with advantage superseded by a leather gauntlet to be worn for a further period.

Compound dislocations should be treated as conservatively as possible. A loose carpal bone may need removal, or in some cases a partial resection may be advantageous; but amputation should be decided on only in the case of hopeless injury, or in a patient wholly unfit to take the risks of the process of healing.

Dislocation of the Individual Bones of the Carpus.—Of the first row, the pisiform is occasionally displaced by the action of the flexor carpi ulnaris or by direct violence. The bone usually acquires fresh attachment, and the injury is of little importance. The scaphoid and semilunar have also been seen to be dislocated, usually in compound injuries. In such a case the displaced bone may be removed.

Of the second row, the os magnum is most frequently displaced—seldom completely, however, the head and neck only projecting dorsalward as a result of the rupture of the transverse ligament which crosses from the scaphoid to the cuneiform. This portion of the os magnum sometimes acquires a prominence as a result of habitual strain due to the occupation of the individual. In traumatic dislocation it is best reduced by direct pressure, the middle finger being at

the same time drawn upon. If painful and irreducible, it may be removed.

Separation of the two rows of the carpus is very rare.

Metacarpus.—The fixity of the carpometacarpal junction makes dislocation of these bones one of the rarest occurrences. As would be expected from the mobility and exposed position of the metacarpal bone of the thumb, the first bone is the one most commonly displaced; and this will be treated of specially. Of the others, the second and third are most exposed by reason of their comparative length. Most of the recorded instances have been of the first finger. A case is figured in Erichsen's *Surgery*, in which the four bones were apparently dislocated *en masse*.

Symptoms.—On inspection there appears either a dorsal prominence or a hollow bounded by the line of the second row of carpal bones, according to whether the metacarpal bone has passed backward or forward. The finger is shortened and slightly flexed. In Erichsen's case the fingers are extended and abducted. On palpation the above points will be corroborated.

Apart from complete traumatic dislocation of these bones, it should be mentioned that the bases of the bones, especially the third, are occasionally partially displaced backward, and form a dorsal prominence bounding a slight hollow. Such displacements may follow a fall on the hand, or are the result of hard manual labor. They usually do not call for treatment.

Recent traumatic dislocations are to be reduced by traction on the corresponding finger or fingers, combined with direct pressure downward and forward, or backward, as the case may be.

Metacarpal Bone of the Thumb.—The joint between this bone and the trapezium differs from the others not only in its greater mobility as to flexion and extension, but also in possessing free lateral movement. Displacement may be dorsal or palmar, and usually results from falls on the palm of the hand, leading to hyperextension; but it may be caused by forcible flexion with adduction.

Symptoms.—In *dorsal dislocation* the wrist and the phalanges of the thumb are slightly flexed, a prominence is seen on the dorsum of the carpus slightly internal to the normal position of the base of the bone, and the tabatière anatomique is deepened. The thumb is shortened. On palpation the base of the metacarpal bone is approximated to the styloid process of the radius. The displacement may be incomplete, when these signs will be less strongly marked.

Palmar dislocation is rarer than the dorsal. A hollow takes the place of the prominence mentioned in the last form, while the base of the metacarpal bone may be felt on the palmar aspect of the trapezium. The thumb is extended, and opposition is impossible. The phalanges may be moved freely.

Treatment.—The dislocation is readily reduced by traction in the axis of the displaced bone, combined with direct pressure on the base in a downward direction, and either forward or backward, as the case may be. If this fails, hyperextension may be tried; also hyperextension combined with direct pressure. The thumb should then be fixed in a position of full extension, with a pad over the base of the metacarpal bone.

ward to pass beneath the annular ligament. On manipulation, all movements are interfered with. Measurement shows: (*a*) the length of the radius from its head to the tip of the styloid process to be equal to that of the opposite limb; (*b*) the distance from the upper margin of the dorsal prominence to the tip of the middle finger to equal that from the line of the radiocarpal joint to the same point.

In *forward dislocation*, the dorsal prominence is concave from side to side, and in a recent injury the styloid processes are visible. The palmar prominence is convex upward, and somewhat obscured by the thickness of the flexor tendons. On palpation and measurement, the signs resemble those already detailed in the case of the dorsal displacement, except in regard to the reversal of the top level of the prominences (the palmar being the higher), the concave outline of the dorsal prominence, and the possibility of tracing the outline of the radio-ulnar arch.

Diagnosis.—If the points above detailed under the heading of Symptoms be borne in mind, no difficulty should occur in the verification of this injury. Colles's fracture and separation of the lower radial epiphysis are the only stumbling-blocks; and confusion with either of these is readily avoided by attention to the relative position of the bony landmarks.

Prognosis.—Reduction is easy, and, in spite of the shallowness of the joint-cavity, no marked disposition to recurrence has been observed.

Treatment.—The displacement is readily reduced by traction in the axis of the displaced hand, combined with direct pressure on the dorsal or palmar prominence, as the case may be. The hand and forearm should then be placed on anterior and posterior splints, well padded opposite the position of the late carpal prominence, the fingers being allowed to project, so as to guard against subsequent stiffness from fixation of the tendons. After fourteen days the splint should be removed daily, the hand and forearm massaged, and careful movement of the fingers carried out. The splints should be retained for four to five weeks, and in many cases may be with advantage superseded by a leather gauntlet to be worn for a further period.

Compound dislocations should be treated as conservatively as possible. A loose carpal bone may need removal, or in some cases a partial resection may be advantageous; but amputation should be decided on only in the case of hopeless injury, or in a patient wholly unfit to take the risks of the process of healing.

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Of the second row, the os magnum is most frequently displaced—seldom completely, however, the head and neck only projecting dorsalward as a result of the rupture of the transverse ligament which crosses from the scaphoid to the cuneiform. This portion of the os magnum sometimes acquires a prominence as a result of habitual strain due to the occupation of the individual. In traumatic dislocation it is best reduced by direct pressure, the middle finger being at

the same time drawn upon. If painful and irreducible, it may be removed.

Separation of the two rows of the carpus is very rare.

Metacarpus.—The fixity of the carpometacarpal junction makes dislocation of these bones one of the rarest occurrences. As would be expected from the mobility and exposed position of the metacarpal bone of the thumb, the first bone is the one most commonly displaced; and this will be treated of specially. Of the others, the second and third are most exposed by reason of their comparative length. Most of the recorded instances have been of the first finger. A case is figured in Erichsen's *Surgery*, in which the four bones were apparently dislocated *en masse*.

Symptoms.—On inspection there appears either a dorsal prominence or a hollow bounded by the line of the second row of carpal bones, according to whether the metacarpal bone has passed backward or forward. The finger is shortened and slightly flexed. In Erichsen's case the fingers are extended and abducted. On palpation the above points will be corroborated.

Apart from complete traumatic dislocation of these bones, it should be mentioned that the bases of the bones, especially the third, are occasionally partially displaced backward, and form a dorsal prominence bounding a slight hollow. Such displacements may follow a fall on the hand, or are the result of hard manual labor. They usually do not call for treatment.

Recent traumatic dislocations are to be reduced by traction on the corresponding finger or fingers, combined with direct pressure downward and forward, or backward, as the case may be.

Metacarpal Bone of the Thumb.—The joint between this bone and the trapezium differs from the others not only in its greater mobility as to flexion and extension, but also in possessing free lateral movement. Displacement may be dorsal or palmar, and usually results from falls on the palm of the hand, leading to hyperextension; but it may be caused by forcible flexion with adduction.

Symptoms.—In *dorsal dislocation* the wrist and the phalanges of the thumb are slightly flexed, a prominence is seen on the dorsum of the carpus slightly internal to the normal position of the base of the bone, and the tabatière anatomique is deepened. The thumb is shortened. On palpation the base of the metacarpal bone is approximated to the styloid process of the radius. The displacement may be incomplete, when these signs will be less strongly marked.

Palmar dislocation is rarer than the dorsal. A hollow takes the place of the prominence mentioned in the last form, while the base of the metacarpal bone may be felt on the palmar aspect of the trapezium. The thumb is extended, and opposition is impossible. The phalanges may be moved freely.

Treatment.—The dislocation is readily reduced by traction in the axis of the displaced bone, combined with direct pressure on the base in a downward direction, and either forward or backward, as the case may be. If this fails, hyperextension may be tried; also hyperextension combined with direct pressure. The thumb should then be fixed in a position of full extension, with a pad over the base of the metacarpal bone.

Metacarpophalangeal and Interphalangeal Joints.—The joints between the metacarpus and the phalanges, and the interphalangeal joints in a less degree, are peculiar in the nature of the ligament forming the anterior segment of the capsule. This consists of a fibro-cartilaginous plate, loosely attached to the proximal bone, but firmly blended with the base of the distal one. This arrangement, while scarcely disposing to the occurrence of dislocation, forms a difficulty in the reduction of the phalanx, since the plate, especially in the case of the metacarpophalangeal joint, is apt to be actually drawn over the head of the proximal bone, and to interpose itself between the displaced bones. The tenuous dorsal segment of the capsule offers little obstacle to displacement.

Thumb.—The metacarpophalangeal joint of the thumb must be considered alone. In the other joints four angular movements are possible; in the case of the thumb lateral movements are shifted one segment back, giving greater range with a shorter digit, and at the same time endowing the distal joint with the fixity necessary for its safety. Beyond this the glenoid plate consists of two sesamoid bones and an intervening bond, an arrangement in part responsible for the difficulties met with in the reduction of dislocations of this articulation.

In 812 dislocations met with at St. Thomas's Hospital, 74 were of the thumb, or 9.1 per cent. The 74 were distributed as follows: Carpometacarpal, 1; metacarpophalangeal, 35; interphalangeal, 32; unstated, 6. In Krönlein's statistics the percentage amounted to 6.7.

Causation.—In the commoner or dorsal dislocation the accident is usually the result of a fall on the outstretched palm. The palmar dislocation may be caused by violent flexion or direct violence.

Pathology.—The dorsal dislocation may be complete or incomplete. In the former the capsule suffers injury to the glenosesamoid plate, which is torn from its connection to the metacarpal bone; and the anterior parts of the lateral ligaments, especially the outer, are usually torn also. The dorsal ligament may escape, but is ruptured if the phalanx passes far on to the dorsum of the metacarpal bone. Little injury is suffered by the short muscles of the thumb, the outer head of the flexor brevis pollicis being the only one torn, and this in its anterior part, and not sufficiently to separate it from its sesamoid bone. The tendon of the long flexor is usually displaced inward, lying behind the prominence of the head of the metacarpal bone, on the expansion of the short muscles.

The difficulty experienced in the reduction of this dislocation has been variously attributed to the tight grasping of the neck of the metacarpal bone by the slit in the capsule, to the contraction of the short muscles and a similar gripping of the head between them, and to the interposition of the capsule or parts of it between the joint-surfaces. Of these three explanations, it is not possible to exclude entirely the first two; but they appear to have depended on an incomplete attention to the peculiarities of the anterior segment of the capsule. From what has been already said it will be seen that the primary gap in the capsule depends on the separation of the glenoid ligament from the metacarpal bone—that is, a transverse slit at the proximal part of the joint. In the incomplete dislocations the separated margin is drawn on to the head of the metacarpal bone, together with the sesamoid bones, but does not pass the point of greatest convexity of the head. In this condition no difficulty in reduction is likely to arise. In the complete dislocations, rupture of the anterior parts of the lateral ligaments, particularly the external, enlarges the gap; and this may be further increased by a vertical separation of the two sesamoid bones. The freed margin of the glenosesamoid plate now crosses the dorsal aspect of the head, and forms an actual septum between the margin of the phalanx and the joint-cavity. When unsuccessful efforts at reduction are made, one of two things occurs—either the glenosesamoid plate is bent sharply backward at its point of union with the phalanx, and covers its concave base, forming a wedge which prevents the return of the bones into position by greatly increasing the tension of the lateral ligaments; or, in the movement of flexion, the glenosesamoid plate is flattened out on the dorsum of the metacarpal bone by the pull of the short flexor muscles, its anterior smooth surface resting on the bone, and, the sesamoid

bones being rotated so that their cartilaginous surfaces look backward and outward, the phalanx assuming the extended position, with corresponding shortening of the thumb. Further efforts at reduction now only tend to the production of the first condition described.

Symptoms.—In dorsal dislocation the thumb is flexed at the metacarpophalangeal joint; if the dislocation is incomplete, to an obtuse angle; if complete, to a right angle. In the latter case the thumb is shortened; the distal phalanx is usually flexed and difficult to extend. The phalangeal section is also commonly somewhat adducted. The head of the metacarpal bone forms a palmar prominence. On palpation the head of the metacarpal bone can be felt anteriorly, and the base of the phalanx on its posterior aspect. Care must be taken not to mistake the wide base of the phalanx for the metacarpal head—an error which has been made when the parts were obscured by much surrounding swelling. A continuance of the violence or efforts at reduction may sometimes result in the further displacement mentioned under the heading of Pathology. The phalanx is then extended and parallel to the metacarpal bone; there is considerable shortening of the base of the phalanx, sometimes reaching as far as the middle of the metacarpal shaft, and the vertical diameter of the thumb is nearly doubled.

FIG. 312.—Dislocation of the thumb.

Palmar dislocation is very rare. It is usually the result of direct violence. The dorsal aspect of the capsule is torn, and the glenosesamoid plate separated from the metacarpal bone. On inspection the proximal phalanx is usually flexed, and this position is combined with some vertical rotation of the thumb, due to the inability of the convex oval margin of the phalanx to rest exactly on the convex metacarpal head (Bardenheuer), and also to slight adduction. The distal phalanx is extended. The long extensor tendons cross the angle, or are sometimes interposed. On palpation, the head of the metacarpal bone is readily mapped out, and a corresponding gap in front of it. The base of the phalanx may be felt anteriorly.

Diagnosis.—The differential diagnosis depends on a careful attention to the points above detailed. It should be remembered that dislocations of the thumb are generally accompanied by much immediate swelling and subsequent local inflammation.

Prognosis.—The difficulties of reduction in certain cases have been already alluded to, and will find further mention under the heading of Treatment. The anterior dislocations are difficult to retain in position.

If either dislocation remains unreduced, the function gradually improves with time and use, and may be fair.

Treatment.—In dorsal displacements this consists in hyperextension. The base of the phalanx is pushed forward by one thumb of the operator, while the tip is forcibly pressed upon by the other, so as to tilt the base over the head of the metacarpal bone without danger of interposing the glenosesamoid plate. Some adduction may be combined, if necessary, to utilize the generally wider tearing of the external lateral ligament. The older method of primary flexion of the metacarpal bone together with traction and direct pressure is less satisfactory, as more likely, by releasing and altering the direction of the pull of the short muscles, to allow of interposition of the glenosesamoid plate. The method proposed by Palmer of making a small opening on the palmar surface for the introduction of a lever across the head of the metacarpal bone and beneath the base of the phalanx is worthy of trial. In palmar dislocations the thumb should be fully flexed and direct backward pressure made on the base of the phalanx, while the head of the metacarpal bone is pressed in an opposite direction.

Lastly, if the dislocation defies ordinary methods, the best resort is arthrotomy with a radial incision. Subcutaneous tenotomy has been recommended and much employed—often, however, unsuccessfully, as might be expected if the glenosesamoid plate is the chief cause of difficulty. If arthrotomy fails, excision of the head gives very good results; but it is usually demanded by old cases only. In dislocations of the thumb even the interval of a few days is of great prognostic importance, as far as reduction is concerned. Compound dislocations are to be treated conservatively, resection being admissible only in special cases. Good results are generally obtained.

Metacarpophalangeal Joints of the Fingers.—Dislocations of these joints are uncommon, although not so rare as old statistics would lead us to believe. Thus, of 812 dislocations of all joints observed at St. Thomas's Hospital, 86, or 10.59 per cent., were of the fingers. These were distributed as follows: Metacarpophalangeal, 14; first interphalangeal, 20; second interphalangeal, 17; and joint unstated, 35.

These joints differ from that of the thumb in the possession of lateral mobility, and in the anterior ligament being a simple glenoid plate without sesamoid bones. Dislocation is most commonly dorsal, rarely palmar, and in the case of the index and little fingers lateral displacement has occasionally been observed. The ring finger is very rarely dislocated.

Symptoms.—The signs vary only slightly in degree and in the different outline of the joint from those already detailed fully in the case of the thumb, and the same methods of reduction may be tried.

Interphalangeal Joints.—The anatomy of these joints resembles that of the metacarpophalangeal, varying only in the lesser degree of strength and in the presence of a double condylar head to the phalanges. The dorsal and palmar displacements are accompanied by precisely similar signs to those observed in the proximal joints.

The special variety of dislocation is the partial lateral one. This is due to lateral flexion of the joint, leading to rupture of one lateral ligament and the escape of the phalanx to the corresponding side, the

inner condyle of the proximal phalanx resting in the outer cavity at the base of the distal phalanx, or *vice versâ*, as the case may be. These dislocations are unaccompanied by shortening or by marked flexion. The finger is usually extended, the long axis is distorted, and lateral prominences are to be felt corresponding to the uncovered condyle of the proximal phalanx and the base of the distal one. All are best treated by traction and direct pressure on the displaced bone. What has been said as to the treatment of compound dislocation of the thumb holds good here.

Tibia.—According to the general mode of classification, dislocations of the knee are regarded as displacements of the tibia; but it should be pointed out that in all cases it is the femur which bursts the capsule, and therefore takes the more active part in the production of the injury.

As the central joint of the long lever formed by the lower extremity, the knee has to withstand greater strain than any other articulation in the body. Its power to do this depends on several special characteristics. In the first place, the bony contact exceeds in surface-area that of any other joint in the body. A very shallow cavity is, however, offered by the tuberosities of the tibia—a point of importance as to the possible occurrence of dislocation, since no bony prominence exists to act as an abnormal fulcrum in forced movements of the joint and throw excessive strain on the ligaments. The stability of the joint depends further on the density of the surrounding fascia with its abundant muscular insertions, the numerous surrounding tendons, the strength and number of the ligaments, especially the crucial, and the special arrangement of the interarticular cartilages, by which a contact of the bony surfaces, as exact and extensive as possible, is ensured in all positions, in spite of the variations in the curve of the condyles of the femur. The substitution of muscular expansion for a strong capsule on the aspect of the joint most affected by its movements finds here its most striking example in the arrangement of the quadriceps tendon; while in the oblique fasciculus of the posterior ligament we have an excellent example of the strengthening and modification in character of a ligament by the addition of a tendinous insertion—that of the semimembranosus. The importance of the latter arrangements to the stability of an articulation, such as the knee, is evident, since, if taken by surprise, the strain is not thrown against an inelastic band of white fibrous tissue, like a pure ligament, but against a structure which is to some extent under a muscular or contractile control capable of breaking and modifying a sudden shock.

Frequency of Occurrence.—Dislocations of the tibia are rare. In 812 dislocations seen at St. Thomas's Hospital, 1 example occurred, or 0.123 per cent. In Krönlein's statistics, 4 occurred in a total of 400 dislocations, or 1 per cent. Not one of the whole 5 was complete.

Causation and Classification.—The sagittal dislocations generally, and the lateral always, are the result of indirect violence, and are caused by falls on the feet followed by an excessive movement of the knee, due to the further progress of the body. Forward displacement usually results from hyperextension, such as may be caused by falling forward of the body when the foot and leg are fixed in a hole. The condyles of the femur reach the anterior border of the tibia, and are thrown against the posterior part of the capsule; this and the posterior part or whole of the lateral ligaments are ruptured by the condyles, and a dislocation occurs. In the lateral dislocations a movement of abduction or adduction of the knee in the same way throws the femur against the opposite lateral ligament, which is ruptured, and allows a dislocation to be produced in the opposite direction. The sagittal displacements may also be produced by direct violence; thus, an anterior dislocation may result from the falling of a heavy body on the front of the thigh with a flexed knee, the femur being driven backward; or a posterior dislo-

cation may result from a blow received by the anterior aspect of the tibia with a slightly or fully flexed knee. A case of lateral dislocation from violence exerted on the side of the thigh with a fixed leg has also been recorded.

Pathology.—A large proportion of the forward dislocations are incomplete, a still larger of the posterior, while the lateral are nearly always incomplete.

Symptoms.—In *forward dislocation* the knee is usually extended or hyperextended, the latter position causing a posterior inflexion. The tubercle of the tibia is very prominent. From it the tense ligamentum patellæ slopes backward, with a hollow on either side, and above this the patella itself is seen bounding a considerable hollow over the lower end of the femur. The popliteal hollow is obliterated, and the anteroposterior diameter is considerably increased. In complete dislocation shortening of from 1 to 4 inches has been observed. On palpation the anterior margin of the head of the tibia is felt on either side of the ligamentum patellæ, and in complete dislocations the outline of the facets on its upper surface can be made out. The patella itself lies in a more or less sloping position over the upper end of the tibia. The expansion of the quadriceps is loose and in folds which obscure the upper margin of the patella. Posteriorly the condyles are readily felt, and, when the gastrocnemius is much lacerated, may be actually subcutaneous. On manipulation little movement is possible, unless the ligamentous laceration is unusually free, and then the leg simply hangs loosely. The vessels in the popliteal space may be compressed, and there may be great pain from pressure on the popliteal nerves.

FIG. 313.—Backward dislocation of the tibia.

In *backward dislocation* the limb is usually extended or hyperextended. The same increase in the anteroposterior diameter is observed as in the forward variety, and if the dislocation is complete there is shortening of the leg. Anteriorly a prominence is seen above the level of the joint-cleft, consisting of the condyles of the femur; posteriorly, one due to the displaced head of the tibia, which may be above or below the level of the joint-cleft, according as the displacement is complete or not. Hollows exist below and above these prominences, and the outline of the ligamentum patellæ may be observed crossing the anterior one.

On palpation the outline of all the upper part of the trochlea may be mapped out on the prominent condyles, while on either side of the ligamentum patellæ the under surface of the condyles may be felt.

In complete dislocation the patella itself is horizontally applied to the under aspect of the condyles in their center. The prominent margin of the head of the tibia may be felt posteriorly. On manipulation little movement is possible, and this only in the direction of flexion, together with some abnormal lateral mobility.

Lateral dislocations are seldom complete, and as the movement of forced abduction is so much more frequent than that of adduction, displacement outward is the commoner variety.

On inspection the limb is usually found extended, the foot rotated out in the outward variety, and the reverse when the displacement is inward. The lateral diameter of the limb is increased. A prominence exists on either side, that above the level of the joint-cleft corresponding with a femoral condyle, the skin-covering of which is usually tense and shining, and that below corresponding with a tibial tuberosity. On palpation the outline of the condyle and tuberosity respectively can be mapped out, and the trochlear surface of the femur is also traceable, since the patella is carried with the tibia over the margin of the condyle.

Prognosis.—Immediate reduction is seldom difficult; indeed, the bystanders after one of these accidents have not unfrequently reduced the dislocation by pulling the leg. The prognostic importance depends on the extensive ligamentous rupture, which leaves permanent weakness, and may be followed by deformity, such as bowed leg or knock-knee. In simple cases the most serious complications are dependent on injury to the vessels. Gangrene has been seen to occur, either within the first few days or as late as the fourth week. In this respect backward dislocations have proved themselves more dangerous than forward ones, since the artery has not the advantage of the protection offered by the popliteal notch of the femur.

Treatment.—The simplest method of reduction is the best, and is generally applicable. Traction is made in the axis of the displaced bone, while direct pressure is made on the two articular extremities in the required direction—*i. e.*, backward or forward for the femur, and downward for the tibia. If this fail, traction followed by flexion may be tried in the forward and backward varieties. If necessary, the forearm of an assistant may be placed in the popliteal space, both to produce some extension and to act as a fulcrum. In the lateral varieties a combination of abduction or adduction, whichever has led to the original injury, will be best combined with traction.

After-care needs to be very prolonged. A fixed support, such as a plaster-of-Paris splint, must be constantly worn for at least six weeks, and should be removed only for the application of massage to the muscles above and below the joint. Gentle passive movement may then be made, and as strength increases, active exercises should be cautiously commenced. A hinged lateral support should be worn for at least a year, and it may be advisable to retain it still longer if there is any appreciable lateral weakness. Compound dislocations are very rare, and must be treated on general principles. Commonly the only substitute for conservative treatment is amputation.

Congenital dislocation is occasionally met with, and may be symmetrical.

Isolated Dislocation of the Fibula.—This accident is a rare one. The upper end of the bone is occasionally displaced by direct violence or by forcible contraction of the biceps. It may also complicate a fracture of the upper third of the tibia. A case is on record in which both ends were separated, dislocation first occurring at the ankle, and the bone being then driven bodily upward.

Symptoms.—Displacement of the upper end is readily recognized by palpation of the head, which is situated either too far forward or backward, and in one recorded case was upward. The outer surface of the leg is flattened, a depression takes the place of the normal prominence of the head, the biceps tendon is tense, and power of extension of the leg is more or less impaired.

Treatment.—The head should be reduced by direct pressure, and the limb slightly flexed and put up in plaster of Paris. The small area of the joint-surfaces and the pull of the biceps are unfavorable to a good result. Small inconvenience, however, seems to have resulted, but the obvious treatment is to fix the head of the bone to the tibia, either by a screw or a suture.

Patella.—The position of the patella is maintained by the various parts of the quadriceps extensor cruris, any vertical movement being necessarily controlled by the attachment of the ligament to the tibia. Lateral shifting, however, is possible in the groove of the femoral trochlea, especially in the extended position.

The obliquity of the thigh necessitates a corresponding slope in the inward direction of the quadriceps, which is, however, to a small degree reversed in the ligamentum patellæ. Hence, in the normal state the patella forms the apex of a triangle, salient inward. To neutralize the consequent tendency to outward displacement of the knee-cap when the muscle contracts, we find that the vastus internus has a much more extensive muscular insertion into the inner patellar margin than the vastus externus has to the outer. In spite of this arrangement, the comparative frequency of outward displacements and the rarity of inward ones conclusively demonstrate the influence of the anatomical arrangement. In the position of flexion the patella sinks deeply into the intercondylar notch overlying the cleft of the knee-joint, and lateral displacement is opposed by the tension of the quadriceps. In extension, on the other hand, the patella is prominent, rests on the trochlea by its lower part only, and the quadriceps is not stretched; hence, extension is the position of danger for the patella.

Frequency of Occurrence.—In the 812 dislocations seen at St. Thomas's Hospital, 3 were of the patella, or a ratio of .24 per cent. Krönlein saw 3 in 400 dislocations, or .75 per cent.

Causation and Classification.—Dislocations of the patella are usually the result of sudden contraction of the quadriceps, and therefore they are due to muscular action; but they may be caused by direct violence in blows or falls, the margin of the bone being the point of impact.

The bone is commonly dislocated outward; very rarely in the opposite direction. Dislocation outward relaxes the quadriceps, inward tightens it—another reason for the rarity of the inward variety. Dislocation upward results only from rupture of the ligamentum patellæ (Fig. 314). Beyond these forms, a rotatory displacement, in which either the inner or outer margin of the bone rests in the notch between the condyles, occurs; and this may be complete, the articular surface looking forward.

Luxation outward in cases of knock-knee is by no means a

rare spontaneous occurrence, and hence a degree of genu valgum only slightly emphasizing the normal physiological arrangement must be looked upon as predisposing to the occurrence, and no doubt does explain some cases of outward displacement. In congenital displacements of this bone, genu valgum results, and it has also been observed to develop as a result of unreduced traumatic dislocations.

Pathology.—A slit is produced in the side of the capsule opposite that of the displacement. Vertical displacement makes a double slit necessary. Tension of the remaining bands is usually regarded as the cause of the fixation of the bone in false position.

Symptoms.—In lateral dislocations, when displacement is complete, the knee is about one-quarter flexed; in incomplete dislocations it is sometimes extended. The front of the knee is widened, the normal prominence of the patella is shifted to one or the other side, and a hollow exists in its position over the center of the femur, bounded by the prominent margin of the displaced patella. On palpation the position of the patella may be determined, while either the whole or part of the outline of the trochlea may be traced, in addition to the abnormally coursing ligamentum patellæ. On manipulation little movement is possible, and that very painful.

FIG. 314.—Rupture of the ligamentum patellæ; upward displacement of the bone (St. Thomas's Museum, London).

In rotatory dislocation, the knee is extended, a central prominence formed by the margin of the patella increases the sagittal diameter of the limb, and on either side of this is a hollow. On palpation the position of the patella and the direction of its cartilaginous surface are readily determined. The quadriceps is very tense. Complete rotation is seen both as a result of muscular action or complete violence.

Prognosis.—The function of the limb becomes fair, even if the displacement is unreduced; but both flexion and complete extension are somewhat interfered with.

Treatment.—To reduce the displacements, the hip must be flexed and the knee extended, while direct pressure is made upon the patella. If this fails, forcible flexion, followed by extension, may be tried. In suitable individuals, where these methods are unsuccessful, an open incision may be made, and after division of the tense bands of the capsule, the patella may be temporarily fixed in position with a peg or screw. Cases of rotatory displacement, however, are on record where even the open method has failed.

Foot.—The ankle forms one of the purest examples of the hinge-joint, lateral movement being opposed by strong radiating ligaments, and large bony processes extending over the entire lateral aspects. Under these circumstances it will be readily understood that lateral displacements do not occur without fractures of the bones; thus, a partial outward displacement is always treated of as Pott's fracture, and a more complete one as Dupuytren's, while inward displacements are accompanied by fracture of the internal malleolus. These will therefore meet with no further mention here. An upward displacement is often described, the dislocation being not of the astragalus alone, but combined with a diastasis of the inferior tibiofibular articulation. Although there is some doubt as to whether this separation is not actually due, in most cases, to an oblique fracture of the tibia, it demands brief notice here. It has been caused by falls on the foot in a horizontal position. The signs consist in a widening of the transverse diameter of the ankle, approximation of the malleoli to the margin of the sole, and extreme fixity of the foot. Reduction has proved extremely difficult or impossible.

Sagittal Dislocations.—Pure forward and backward dislocations of the foot occur rarely.

Frequency of Occurrence.—In 812 dislocations observed at St. Thomas's Hospital, 1 of backward dislocation occurred, or 0.12 per cent. In Krönlein's statistics, 2 occurred in 400, or 0.5 per cent.

Causation.—The majority of observed instances have been the result of indirect violence, the tibia, strictly speaking, being the bone dislocated. Thus, the backward and more common variety has been caused by falls on the feet, the body falling forward; or the knee and ankle are flexed to a degree in which the tibia bursts the posterior ligament and passes on to the upper surface of the os calcis in its non-articular portion. Again, the tibia has been driven backward by a blow upon the flexed knee while the person was in a squatting position. Thus, the displacement is the result of hyperflexion. Forward dislocation is the result of the opposite movement of hyperextension. In this case again, falls on the feet are the commonest cause. The foot becomes the fixed point, and the body falling backward, the tibia finds an abnormal fulcrum in the posterior margin of the astragalus, and bursts the capsule anteriorly. The leg has been known to form the fixed point, and the foot has been driven forward by direct violence applied to the heel.

Pathology.—Complete dislocation in either direction necessitates rupture of both lateral ligaments. These are very strong, so that in the lateral displacements fracture is common; thus, the internal malleolus has been found fractured in the forward variety, and the external in the backward. Either dislocation may be complete or incomplete. In the complete forward, the tibia rests on the posterior part of the os calcis; in the complete backward, on the fore part of the astragalus and scaphoid. In the incomplete varieties the tibia rests on some part of the articular trochlea of the astragalus by its anterior or posterior margin. Either variety, when complete, causes great tension of the skin, which may be burst or give way secondarily as the result of the injury it has suffered.

Symptoms.—In dislocation backward the foot is extended, and if the external malleolus is broken, somewhat abducted. The dorsum of the foot is shortened. The rounded lower end of the tibia is prominent, and below it a marked groove or crease of the skin corresponds with the cleft of the ankle-joint. The heel projects strongly, and the dis-

tance between it and the malleolus is increased. The tendo Achillis is prominent, and forms a sharp curve, concave backward; a deep hollow exists on either side of it. On palpation the relation of the bony parts can be confirmed, and possibly the astragalus felt in its new position from one or the other side of the tendon. On manipulation little movement is possible, and attempts at it are very painful.

In dislocations forward the foot is moderately extended, the dorsum elongated, the heel deficient in prominence. The tips of the malleoli are approximated to the sole; the tendo Achillis falls vertically. On palpation the malleoli can be felt on either side, in very close proximity to the tendo Achillis; and the upper surface of the astragalus can be traced anteriorly. If the displacement is incomplete in either direction, the signs are similar, but less strongly marked.

Diagnosis.—The main point in the diagnosis of these injuries is the alteration of the relation of the malleoli to the bones of the tarsus. Determination of this, taken with the alterations in the appearance already described, will obviate any source of error.

Prognosis.—Beyond a slightly marked tendency to recurrence, these dislocations offer little difficulty. If unreduced, the function of the foot is much interfered with.

Treatment.—The knee is flexed to relax the tendo Achillis, and traction made on the foot, combined with flexion or extension in the forward and backward dislocations respectively. The foot should then be fixed in a plaster-of-Paris splint. The date for the commencement of passive movement will vary with the amount of the original displacement and the consequent degree of rupture of the lateral ligaments. In any case a three weeks' interval is necessary, and an apparatus is needful for some months. Reduction has been facilitated in difficult cases by tenotomy of the tendo Achillis. In unreduced dislocations, excision should be limited, if possible, to the astragalus, and consist in either partial or complete removal of that bone. The question of lateral arthrotomy with osteoplastic resection of one of the malleoli may also be considered as a substitute.

The skin in these dislocations is not infrequently much contused, and not rarely lacerated. Great care must be exercised in the application of apparatus when the contusion is severe, and also caution in the application of cold. Compound dislocation must be treated on ordinary lines; but it may be remarked that if the wound is other than a puncture from a fractured malleolus, the condition of the soft parts is usually unsuitable for an excision, either partial or complete.

Subastragaloid Dislocations.—The movements of abduction and adduction of the foot on the leg, or the leg on the foot, when the latter is the fixed point, take place in the astragalocalcanean joint, around an oblique axis corresponding with the attachment of the powerful interosseous ligament.

The circumference of the joint is closed by a capsular ligament of varying consistence, but strengthened by the continuation of the internal lateral ligament of the ankle to the sustentaculum tali, and of the middle fasciculus of the external lateral ligament to the tubercle on the outer surface of the os calcis. Limitation of movement in the articulation is due to bony contact; thus, of the posterior and inner part of the astragalus with the posterior part of the calcaneum in adduction, and the head of the astragalus with the fore and outer part of the greater process of the os calcis in abduction. In a too free movement in either

direction, such as occurs in alighting violently on the foot, the body falling to one side or the other, a false fulcrum is established by bony contact, and sufficient force is exerted on the interosseous ligament to tear it from its attachments. The head of the astragalus then bursts its connections with the scaphoid, and a displacement of the remaining bones of the tarsus from the astragalus and the bones of the leg takes place, either in an inward or outward direction. Lateral oblique displacements caused in this way are the most common; but very rarely, probably as a result of a flexed or extended position of the foot, or of direct violence, a more or less anterior or posterior one may take place.

Frequency of Occurrence.—In 812 dislocations observed at St. Thomas's Hospital, 4 subastragaloid occurred, a ratio of .49 per cent. All were of the oblique inward variety. In Krönlein's statistics no instance was noted.

Causation.—Violent adduction or abduction due to falls on the feet, the latter being firmly planted on the ground, or more rarely actually fixed mechanically. With a fixed foot, violence applied laterally to the leg may act in a similar manner.

Symptoms.—In inward dislocation the foot is adducted and rotated inward in its fore part. The inner border is raised and concave. The head of the astragalus forms a prominent swelling on the outer part of the dorsum, while the external malleolus is prominent, and beneath it is a hollow corresponding to the usual position of the os calcis. The internal malleolus is obscured, while below it the sustentaculum tali is prominent, and also the lower inner margin of the os calcis (Fig. 315). On palpation these points can be confirmed, and the articular cavity of the scaphoid may be traced. On manipulation the movements of flexion and extension are allowed to a limited degree;

FIG. 315.—Inward subastragaloid dislocation (St. Thomas's Museum, London).

adduction also may be increased, but abduction is impossible. All movement is very painful.

In outward dislocation the foot is abducted, the fore part externally rotated; but the outer border does not leave the ground, so that an appearance of flat foot is assumed. The internal malleolus is very

prominent and the skin tense over it. Anteriorly the head of the astragalus is prominent. On palpation the above points can be confirmed, the scaphoid may be felt on the dorsum, and along the outer border the margins of the cuboid and os calcis, and a hollow corresponding to the proper position of the astragalar head. On manipulation adduction is impossible, but some flexion and extension can be made; and in the anterior section of the foot there may be some abnormal mobility.

The forward and backward displacements are very rare, and probably result from violence of the same nature as that producing the corresponding dislocations of the ankle.

In the backward dislocation the foot is shortened and the head of the astragalus rests on the dorsum of the scaphoid; the heel is elongated and the tendo Achillis prominent. Some flexion and extension are allowed at the ankle-joint, but little lateral movement.

In the forward displacement the foot is lengthened and the prominence of the heel abolished; movements of flexion and extension at the ankle are possible.

Subastragaloid dislocations are often compound, and frequently complicated by fracture of the neck of the astragalus and of the malleoli, or the tearing off of small fragments of bone with the detached ligaments.

Diagnosis.—Discrimination of the different varieties depends on careful determination of the points above detailed; but it may be repeated that the special characteristic of subastragaloid dislocations, as compared with those of the ankle, is the retention of the proper relation of the astragalus to the malleoli, and the possibility of passive movements of flexion and extension, while adduction and abduction are interfered with.

Prognosis.—Most of these dislocations are reduced fairly easily in the recent state. If left unreduced, a very unsatisfactory foot results. In compound dislocation the prognosis is usually not very favorable, on account of the contusion and laceration and the difficulty of producing and maintaining asepticity.

Treatment.—Reduction is best effected by inducing anesthesia and then flexing the leg on the thigh, the thigh being held by an assistant, who makes counterextension, while the surgeon makes traction on the displaced foot and endeavors to manipulate it into position. Tenotomy of the tendo Achillis may be necessary. When reduced, the foot must be put up in plaster of Paris and be kept at rest for at least six weeks. If reduction proves impossible, the foot should be kept at rest for a few days to allow of settling down of the damaged structures, and the astragalus may then be partially or wholly removed.

In this, as in most compound dislocations of the foot, the use of antiseptic baths cannot be too highly recommended; and as a preliminary to this treatment it is well to suture the displaced bones together, so as to be more or less free as to splints in the movements necessary to the periodic removal of the foot from the bath. The need for care in ensuring that no injurious pressure shall be made on the leg, and in not allowing the tissues to become sodden by a too long stay in the bath, need only be mentioned.

Dislocations of the Astragalus.—The sheltered position of the astragalus makes it strange that it should be the bone of the tarsus most commonly dislocated. This accident is said to occur more frequently than even subastragaloid dislocation. The explanation is no doubt found in the fact that the bone receives directly the whole transmitted weight of the trunk, to disperse it forward and backward to the remainder of the tarsus.

Frequency of Occurrence.—In 812 dislocations of all joints at St. Thomas's Hospital, 2 of the astragalus were observed, or .246 per cent. No instance occurs in Krōnlein's series.

Causation and Classification.—The actual mode of causation of these dislocations is far from clear. It would naturally be expected that the violence producing them would correspond with that producing the sagittal dislocations of the whole tarsus at the ankle—that is, hyperextension in backward, hyperflexion in forward, displacements. Recorded histories, however, do not altogether support this theory, since, for instance, forward dislocation has been observed to occur with a history of either extension or flexion. This may depend in part on the fact that exact histories of an accident caused by sudden and great violence are seldom altogether reliable, but more probably on the nature of the violence exerted, which is seldom simple in direction, but often combined with severe twisting and wrenching.

The bone may be displaced either backward or forward; but in either case a lateral direction is assumed, usually combined with some rotation. Thus, we have forward and inward, forward and outward, backward and inward, and backward and outward varieties. The lateral deviation is determined by the position of the foot at the moment of injury; if abducted, the inclination of the astragalus is inward; if adducted, outward. Displacement may be complete or incomplete, and is often complicated by fracture of the neck of the bone.

The most striking variety is the pure rotatory. Here the astragalus is rotated so as to lie on one side or the other; or it may even be completely reversed, so that the under surface is directed toward the tibia. It may take a horizontal position across the front of the malleolar arch. These versions probably depend on the fact that the primary injury is a severe wrench or twist, in which the astragalus first loses its connection to the bones of the leg and accompanies the rest of the tarsus, from which it is then separated by the final pressure of the weight of the body. On the cessation of the violence, the tendency of the foot is to resume its normal position. The remaining bones of the foot readily do this, the hollow upper surface of the os calcis turning on the displaced and free astragalus. The somewhat angular astragalus, however, cannot so readily turn in its confined space, and hence remains rotated; or the rotation may be increased or completed by the passage of the os calcis to the median line beneath it. Again, supposing a twist severe enough to bring the astragalus forward out of the tibiofibular arch, and then the weight of the body to complete its separation, as the violence is relinquished, the foot tends to resume its position, while the astragalus probably hitches against one of the malleoli, and thus its transverse direction is made more pronounced and permanent.

Pure lateral displacements have been described, but always in cases of a compound nature, and usually in combination with fracture of a malleolus. When the interosseous ligament is completely torn from the astragalus, the main nutrient vessels which enter by the floor of the groove are all torn; hence the frequent occurrence of necrosis.

Symptoms.—In forward displacement the astragalus forms a marked projection on the dorsum of the foot, either to the inner or outer side, according to the lateral direction which it has taken. The prominence resembles in outline the head of the astragalus, and the skin is tense and shining over it. The malleoli are approximated to the margin of the sole. The foot is deflected to the opposite direction to that taken by the head; the corresponding malleolus is prominent, the other sunken. On palpation the trochlea, or part of it, can be felt, as well as the outline of the head. If the dislocation is complete, the head

FIG. 316.—Forward and outward dislocation of the astragalus (St. Thomas's Museum, London).

rests on the cuneiform bones; if incomplete, on either the inner or outer part of the dorsum of the scaphoid, the posterior extremity of the bone still lying beneath the malleolar arch. On manipulation all movement of flexion and extension at the ankle is impossible (Figs. 316, 317).

In backward displacement the foot is extended, the distance between the malleoli and the sole is diminished, and a projection may be present, pushing the tendo Achillis backward, or situated on one side of it or the other, according to the direction taken by the astragalus. In the oblique lateral displacements the skin may be very tightly stretched over this. The tibia is thrown somewhat forward, so that the dorsum of the foot is strengthened. On palpation, the outline of the astragalus can be made out, but the head is usually buried beneath the tibia. A hollow is to be felt between the malleoli anteriorly. The bone is often displaced, so that its upper articular surface looks backward with a lateral deviation, especially when the neck has been fractured. On manipulation, there is no movement in the ankle-joint.

In rotatory displacements inspection offers no definite signs; the diagnosis is one, therefore, of exclusion, aided by careful palpation for the outline of the astragalus. On manipulation, there is little movement at the ankle-joint.

Diagnosis.—The main points are the prominent position of the displaced bone, the outline of which may be traced on palpation, the loss of the proper relation of the points of the malleoli to the astragalus and the sole of the foot, and abolition of the movements of flexion and extension at the ankle.

Prognosis.—Complete separation of the astragalus from its connections may be followed by sloughing of the skin, especially in the for-

FIG. 317.—Backward and inward dislocation of the astragalus, which has assumed a vertical position (Sir W. MacCormac's case).

ward variety. In the backward the bone finds more room in which to accommodate itself, and tension is not so extreme. It should be borne in mind that when complete laceration of the interosseous ligament has taken place, the whole of the vascular supply of the bone has been cut off; hence, necrosis is not uncommon. In the backward dislocations, the foot is sometimes fairly useful, even if the bone be not reduced; but in the forward dislocations, the prominent bone on the dorsum is so painful and liable to injurious compression that the foot is often practically useless.

Treatment.—When the dislocations are simple and incomplete, attempts at reduction are always to be made, and they are usually successful. Reduction is effected by first flexing the leg on the thigh to relax the tendo Achillis; traction is then made on the foot, and direct pressure on the astragalus. If necessary, the tendo Achillis may be divided. The after-treatment is the same as that for sub-astragaloid dislocation. When complete, if not readily reducible, resection of the bone is preferable; and this is almost without exception the best course to pursue when the dislocation is compound.

Dislocation of the Other Tarsal Bones.—The os calcis has been

rarely dislocated alone, generally as the result of fixation of the heel in falls; the cuboid still more rarely, as a result of direct violence. The scaphoid occasionally remains attached to the astragalus and separated from the cuneiform bones when the astragalus is displaced. It has also been displaced with the three cuneiform bones, or again with the addition of the two inner metatarsal bones. The internal cuneiform alone, or the three combined, have also been displaced. All these dislocations are due to direct violence, usually combined with twisting of the foot.

Symptoms.—In all, the displaced bone forms an abnormal dorsal prominence, and in the case of all except the os calcis the foot is shortened, at any rate on the affected side. If left unreduced, a weakened and often painful foot is left. A general rule serves for the reduction of them all: The foot should be extended, and direct pressure made on the displaced bone. The after-treatment consists in fixation for at least six weeks, and possibly a permanent support to the sole. If reduction is impossible, single bones are best resected.

Metatarsus.—The fixation of the second metatarsal bone in the tarsus makes displacement of the whole series almost impossible, unless either the second bone is fractured or the cuneiform bones are disturbed. The entire metatarsus is occasionally displaced, either on to the dorsal or plantar aspect of the tarsus, and with one or other of the above complications in an inward or outward direction.

Symptoms.—When backward dislocation occurs, the foot is shortened, and a prominence, with a groove either before or behind it, is seen in the plantar and dorsal displacements. The foot is usually somewhat adducted, and the hollow of the sole is flattened.

Lateral displacements are always accompanied either by fracture of the second bone, or displacement of the internal cuneiform, when the bones pass inward. There is no shortening of the foot, but some adduction or abduction, according as the displacement is inward or outward. Reduction is usually not difficult, but considerable weakness persists, especially in the lateral displacements. The foot should therefore be kept in a plaster-of-Paris case for at least six or eight weeks, and a support for the arch, preferably a Whitman's brace, may be needed permanently. Compound dislocations of these joints are very uncommon. The first or fifth bone may be displaced individually, or groups, such as the fourth and fifth, the third and fourth, or the second, third, and fourth.

Metatarsophalangeal and Interphalangeal Joints.—None of these displacements is common, no cases being recorded in the series of 812 observed at St. Thomas's Hospital. The rarity depends on the shortness of the digits and their protection by the shoes. The commonest displacement is that of the metatarsophalangeal joint of the great toe; and this corresponds in all respects, even in difficulty of reduction, with the corresponding dislocation of the thumb. Those of the interphalangeal joints also resemble those of the fingers. A good illustration of the plantar variety is often seen in the common deformity of hammer-toe. The mode of reduction differs in no way from that recommended for similar injuries to the hand.

CHAPTER XVIII.

DISLOCATIONS OF THE HIP.

Anatomy.—A correct understanding of the anatomy of the hip-joint is essential to the recognition and reduction of the various forms of dislocations to which it is subject. All advances in our knowledge of these dislocations since Hippocrates have been almost entirely due to a clearer recognition of the bearing of the anatomical structure upon the mechanism of reduction.

At the point of meeting of three strong buttresses, the ilium, the ischium, and the pubis, the firm, rigid, cup-like acetabular cavity receives the globular head of the femur. It lies between two irregular bony surfaces produced by a bend in the innominate bone, meeting at an angle of about 90 degrees the ilio-ischiatic and pubo-ischiatic surfaces, which have been termed by Allis the outer and inner planes of the pelvis. The dividing ridge between these two planes is marked by a line drawn from the anterior superior spine of the ilium through the tuberosity of the ischium (Fig. 318).

FIG. 318.—Outer and inner planes of the pelvis (Allis).

In all dislocations of the femur the head will escape through a rent in the lower portion of the capsule, the strong anterior portion remaining to serve as an important agent in the determination of the signs of dislocation and as an aid to reduction.

Having escaped from the capsule, the head slips off the ridge upon either the inner or outer plane, according to the resultant of the forces producing the dislocation; and upon this basis is made the rational classification of dislocations into inward and outward.

The capsule, which arises from the entire circumference of the acetabular rim where it is thickest, is attached to the anterior intertrochanteric line in front, and to the neck of the

femur, above the posterior intertrochanteric line, behind. Although strong, it is so loose that it allows all ordinary movements of the joint without becoming tense, and hence plays no part in holding the joint-surfaces together.

The acetabular socket is deepened by the cotyloid ligament, a firm, elastic cartilage, which crowns its bony rim, forming an elastic instead of a rigid cushion to check too free motion of the femur, and which, as it fits air-tight to the globular head, constitutes a sucker, enabling atmospheric pressure to maintain the integrity of the joint. The bony surfaces are not, however, held together by atmospheric pressure alone, for the insertions of the gluteus minimus, iliacus, and psoas magnus muscles are such as to enable them to aid in making tense the capsule and giving security to the joint.

The ligamentum teres, a rounded cord covered by synovial membrane, which runs from the depression in the head of the femur to the dome and transverse ligament of the acetabulum, and to which so many varied functions have been ascribed, is now believed (Allis) to be only a distributer of synovia to the dome of the joint, which would otherwise be poorly provided with lubricating fluid. It is too soft and yielding to serve as a true ligament, and in dislocations is generally torn, usually from the head of the femur, and often bringing away a chip of periosteum with it.

The capsule, which extends like a sleeve from the rim of the acetabulum to its insertion into the neck of the femur, as above described, serves (1) to restrain the movements of the femur within safe limits; (2) to furnish surface for muscular attachments; and (3) to form a tight sac to retain the synovia which its inner surface secretes. It presents three thickenings, the first and most important of which, the iliofemoral or Y-ligament (Fig. 319), arises from the anterior inferior spine of the ilium and is inserted into the anterior intertrochanteric line of the femur, the thickest portions of the insertion spreading to the upper and lower ends of the line into which it is inserted, like the arms of a Y. Its importance in the mechanism of dislocations and their reduction was first elucidated by Bigelow, and subsequent observers have been compelled to bear witness to the accuracy of his observations.

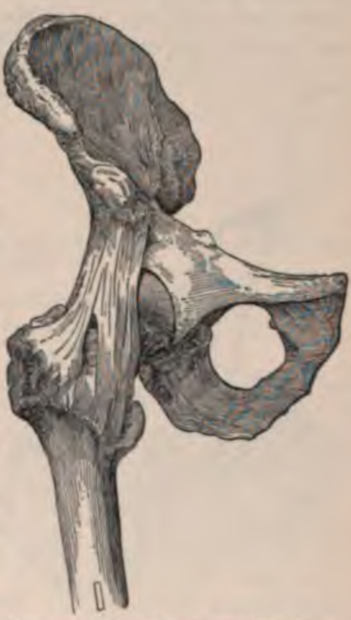


FIG. 319.—The Y-ligament (Bigelow).

Other thickenings of less importance in dislocations and their reduction are the ischiofemoral ligament and the pubofemoral ligament. The former passes from the ischial portion of the acetabular rim on the back of the joint to the posterior surface of the neck of the femur and the posterior intertrochanteric line. The latter arises from the pectineal line as far inward as the spine of the pubis, and passes outward to blend with the capsule, being continuous at its edge with the iliofemoral ligament.

The fact that the capsule is thickest at its pelvic attachment gives it strength at the point where the tension must be greatest when the head of the femur is pressed against it in a dislocating strain. Close to the pelvic attachment the head will impinge upon it, and it is here, therefore, that its thickness gives it greatest resisting power. The

thickening of the inner and outer branches of the Y and ischiofemoral ligaments takes place at the points where greatest strain is brought to bear upon them in circumduction of the joint, the strength being in proportion to the resistance required.

The femoral vessels are rarely injured in dislocations. The reasons are—first, that they lie on the upper surface of the joint, and dislocations are invariably at first downward; second, they are separated from the joint by the pectineus and iliopsoas muscles, which contract and lift them out of the way of the dislocated head.

The fascia lata, while it plays no active part in the mechanism either of dislocations of the hip or of their reduction, has an important function in holding the head in its socket after reduction. In normal dorsal recumbency the iliotibial band, extending as a broad, unyielding belt from the crest of the ilium to the outer side of the head of the tibia, limits the outward rotation of the leg produced by gravity. When the heels of the patient are tied together after the reduction of a dislocation, the iliotibial band is stretched tightly across the great trochanter and holds the head of the femur firmly against the socket.

When the femur is flexed upon the pelvis, the sciatic nerve and hamstring muscles are wound across the back of the hip-joint; and if at the same time the leg is extended upon the thigh, thus separating the origin and insertion of these muscles, they, with the sciatic nerve, are tightly stretched across the back of the neck of the femur. It is in the position of flexion of the joint that dislocations of the hip take place and are reduced, and it is only within the last few years that attention has been called to the importance of the relations of the nerve and muscles to these dislocations and their reduction. Allis has shown experimentally that when a thyroid is transformed into a dorsal dislocation, the head of the femur must pass between the hamstring muscles with the sciatic nerve and the acetabulum, and that the nerve is almost always more or less bruised and torn away from its attachment to the hamstring tendon, and sometimes caught and forced backward by the neck of the femur (Fig. 320). If the nerve has been so separated from the hamstrings, it dangles as a loose cord across the opened acetabulum; and, if in the reduction of the dislocation, which has now become dorsal, a long circumductive sweep is employed, and especially if the leg be so extended on the thigh as to tighten the nerve, there is danger that the nerve may be actually caught up and stretched over the front of the neck of the femur. It is then so shortened that full extension of the thigh cannot be made. This condition has been produced experimentally by Allis and verified by the writers. It has been noted clinically by Allis in a case under the care of Koons of Philadelphia (Figs. 321, 322).

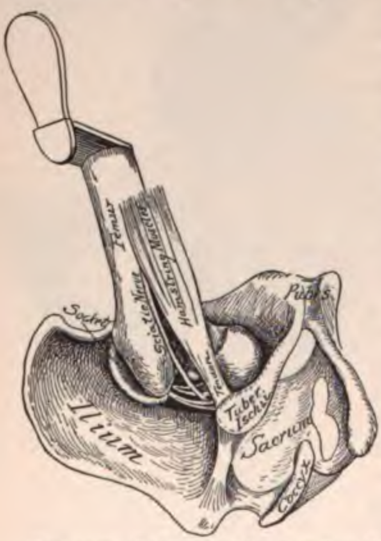


FIG. 320.—Relation of head and neck of femur to hamstring muscles and sciatic nerve in thyroid dislocation (Allis).

To the obturator internus muscle, to its strength, and its importance in backward dislocations in preventing the head of the femur from passing up upon the dorsum ilii, Bigelow

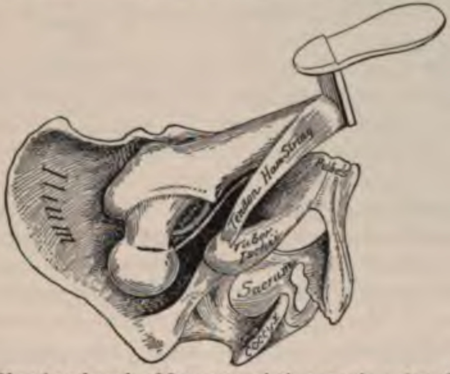


FIG. 321.—Relation of head and neck of femur to sciatic nerve in a dorsal dislocation produced from a thyroid (Allis).

called attention. He established a special class of dorsal dislocations, called dorsal below the tendon. The internal obturator has, however, been so frequently found ruptured at

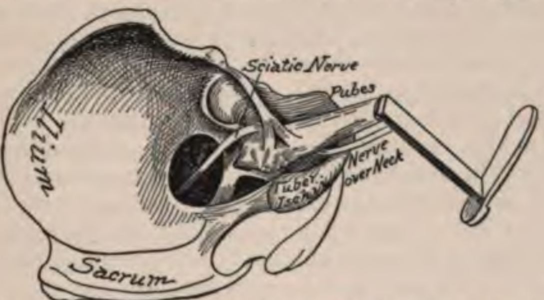


FIG. 322.—Sciatic nerve pressed up by neck of femur in reduction of a dorsal dislocation produced from a thyroid (Allis).

autopsies and experimental work, even when the head of the femur had a low position, that Allis is inclined to ascribe less importance to it in determining the character of a dislocation.

Classification.—Allis's classification, based upon the fundamental distinction between inward and outward dislocation, according as the head rests upon the inner or outer plane of the pelvis, is rational and simple. All the forms enumerated by Bigelow—pubic, subspinous, dorsal below the tendon, etc.—can, as Allis has shown, be brought under the heading of the inward or thyroid and outward or dorsal dislocations. The head may assume a high or low position after it has passed out upon the inner or outer plane of the pelvis. A brief comparative study of the two classifications will illustrate the comparative simplicity of Allis's method (see page 654).

Bigelow's "dorsal below the tendon" becomes the "low dorsal of Allis," his "pubic and subspinous" the "high thyroid." It is evident that after its escape from the capsule, the head of the femur may, under the influence of the forces which are effective in each particular case, come to rest at any position within the radius allowed by the distance from the origin of the untorn part of the capsule to the femoral head.

BIGELOW'S CLASSIFICATION.

1. Dorsal high.
2. Dorsal below the tendon.
3. Thyroid.
4. Pubic and subspinous.
5. Anterior oblique.
6. Supraspinous.
7. Everted dorsal.

ALLIS'S CLASSIFICATION.

1. Thyroid or inward.
   a. Low.
   b. Middle.
   c. High.
   d. Reversed.
2. Dorsal or outward.
   a. Low.
   b. High.
   c. Reversed.

"Everted dorsal" and supraspinous dislocations are simply dorsal dislocations in which the outer branch of the Y-ligament is ruptured, allowing in the former case eversion of the leg and foot, and in the other allowing the head of the bone to move upward and hook over the intact portion of the ligament, with the foot everted. These both are included in Allis's more accurate term "reversed dorsal."

The anterior oblique dislocation of Bigelow is probably an everted dorsal dislocation, in which the outer branch of the Y-ligament, unruptured, engages the femoral head which has passed above it, and prevents the leg from being brought parallel with its fellow.

Mechanism.—The older writers on the subject, up to and including Bigelow, have held that the chief agent in the production of dislocations of the hip was thrust—thrust backward, or backward and upward with the thigh flexed in dorsal dislocations, thrust inward with the thigh abducted and extended in thyroid dislocations. This theory of the mechanism was perhaps the result of a superficial view, suggested by the nature of the accidents by which dislocations are commonly produced. Such accidents as the catching of the flexed femur between two freight cars, a fall into a narrow hole upon the extended leg while walking, etc., certainly suggest thrust as an important element of their production.

Allis alludes to the fact that no experimenter has ever been able to produce dislocation of the hip-joint in the cadaver without previous tenotomy of the capsule, and gives methods by which both the thyroid and dorsal dislocations may be produced experimentally by leverage. The femur is the lever and the pelvis the fulcrum. In previous experiments leverage has failed to produce dislocations, owing to imperfect fixation of the pelvis. In the production of traumatic dislocations in actual life, which all take place in accidents where great force and suddenness are combined, the inertia of the body under the influence of the sudden twist fixes the fulcrum—the pelvis. In order, then, to imitate nature in experimental work, it is necessary to fix the pelvis so that it may serve as a fulcrum. This Allis did by means of screws and cross-bars. He found:

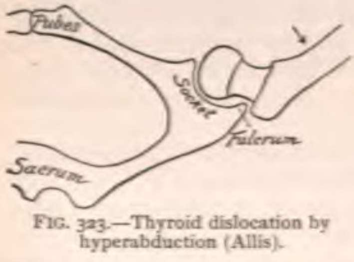


FIG. 323.—Thyroid dislocation by hyperabduction (Allis).

1. That thyroid dislocations might be produced without previous tenotomy of the capsule, simply by hyperabduction of the thigh on the pelvis. The great trochanter is brought against the outer part of the acetabular rim, which offers a bony fulcrum, and the head of the femur is pried with almost

irresistible force through the lower and inner portion of the capsule (Fig. 323).

(Bigelow[1] alludes to abduction as entering into the causation of this variety.)

2. That dorsal dislocations may be produced, if the pelvis is fixed, by flexion of the thigh, adduction, and rotation inward, using the leg bent at the knee as a crank for the production of rotation. By this maneuver the iliofemoral ligament is wound tightly around the front of the neck of the femur, and serves as a fulcrum. The head of the femur, rotated against this fulcrum stretched across the neck, with the great leverage supplied by the use of the bent leg as a crank, is forced outward through the tense posterior portion of the capsule, provided that, as sometimes happens, the ligaments of the knee do not give way under the strain.

Attempts to dislocate the femur by flexion, abduction, and rotation outward—namely, by using the bent leg as a lever and turning it inward—have in the hands of Allis proved uniformly unsuccessful. The pelvis, the ligaments of the knee, or the femur itself may be fractured; but the head of the femur, which is brought directly against the strong anterior portion of the capsule, re-enforced by the Y-ligament, cannot be forced through that structure.

Allis's explanation of the manner in which leverage may be shown to explain the typical accidents resulting in dislocation of the hip, is as follows:

The first case is that of a man who, while walking, steps into a long, narrow hole, and falls forward upon his extended leg. These conditions first suggest thrust; but a consideration of the conditions illustrated by Figs. 325, 326, will show that the force of the straightened leg, acting upon the inner right-hand corner of the trunk as it falls forward, must push the capsule of the hip upward, backward, and outward—in other words, must produce an extremely rapid and forcible flexion, adduction, and inward rotation. Thus, the most advantageous conditions for the production of dorsal dislocation by leverage are produced.

The second case is that of a tramp sitting upon the narrow foot-wide platform at the rear end of a freight car, with his left femur extended and resting upon a similar platform of the following car. The cars come together as the train slows up, and his left femur is dislocated upon the dorsum ilii. Here it is easy to see that the force explodes suddenly upon the left-hand corner of the pelvis, causing flexion, adduction, and rotation inward (Figs. 324–326).

A man shovelling ballast in the hold of a ship, standing with his feet between the ribs, and stooping, is struck upon the back and pelvis by a cave-in from above. A dislocation of both femurs is produced, one outward and the other inward. Here the body is flexed upon the thighs, and the fixation is at the same time suddenly increased by the weight falling from above; but if the body rotate either to one side or the other, the legs remaining parallel, then in one thigh flexion, adduction, and rotation inward are produced, with flexion, abduction, and rotation outward in the other. In this way a dorsal dislocation of one hip and a thyroid of the other will be the result.

These typical cases, then, may be so explained as to support the theory of Allis, that all traumatic dislocations unaccompanied by fracture are the result of leverage.

Pathology.—The importance of the almost uniform escape from rupture of the iliofemoral ligament in dislocations of the hip was established by Bigelow and confirmed by all subsequent writers; but

[1] *Dislocations of the Hip*, p. 70.

the view of this author that the head of the femur frequently escaped through a narrow opening or slit in the capsule, which might require special manipulations in order that it might be made to gape so as to allow the return of the head, has not been confirmed. The results of autopsies and the experimental work of Morris and Allis have shown that the head of the femur, in escaping through the capsule, always makes a rent ample for its return. The reasons for this are the inelas-

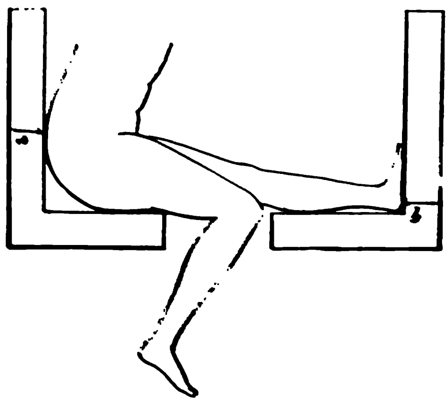
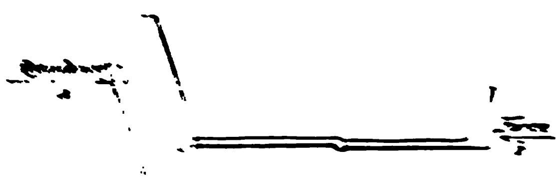


FIG. 524.—Illustrating the mechanism of case 1 (Allis).



[illegible]—Diagram illustrating cases 1 and 2 (Allis).

[illegible]

[illegible]

(Figs. 327–329) illustrate the difference between these positions of the capsular rent; and it is evident that in the last form the avulsed capsule may become interposed between the head and the acetabulum so as to fill the socket and prevent reduction. The closer the rent in the capsule lies to the acetabular socket, the less will be the likelihood of its

FIGS. 327–329.—Illustrating the three forms of the capsular rent.

interfering with reduction by becoming folded in; and if the rent is close to the socket, this folding in cannot take place.

The injuries to muscles in dislocation of the hip result either from overstretching or from direct violence. Those due to overstretching, which are frequently produced in experimental work upon the rigid muscles of the cadaver, result from the fact that the limit of tension of the muscles is reached before the capsule is ruptured by the manipulations employed. In experimental work the production of thyroid dislocation by hyperabduction is attended by rupture of the adductor longus, gracilis, and pectineus. The pectineus is frequently found ruptured at autopsies, and is not touched by the head of the femur during dislocation.

By direct contact with the head of the femur in passing from a dorsal to a thyroid position, or from the inner to the outer plane of the pelvis, the quadratus femoris, obturator externus, and a few of the short upper fibers of the adductor magnus are ruptured. In dorsal dislocations the obturator internus is often ruptured, as are also the pyriformis and quadratus femoris. The head of the femur may pass between the obturator internus and the pyriformis without injury to these muscles.[1]

The fact that in this form of dislocations the obturator internus is often found to be ruptured or avulsed from its origin renders it probable that too much importance was attached to this muscle by Bigelow as the determining factor in low dorsal dislocations.

The sciatic nerve has been twice found at autopsy torn completely in two, and has frequently been reported as lacerated or bruised, with more or less separation of its fibers. It has been frequently hooked up across the neck of the femur in the experimental production of dislocations.

Partial, complete, temporary, and permanent paralyses have resulted from apparently successful reductions. Rupture of the outer branch of the Y-ligament allows the dorsal dislocations to become the everted dorsal.

The older writers on dislocation of the hip have considered the rapid healing of the rent in the capsule after the escape of the head, and the formation of adhesions between the capsule and the acetabular socket, as among the greatest obstacles to the reduction of dislocations. While the dislocation persists, however, the edges of the torn capsule are held apart, so that there can be little danger of healing; and Allis has pointed out that the formation of adhesions between the smooth inner surface of the capsule and the acetabular socket, both of which are covered with epithelium, is extremely improbable.

[1] The possibility of the head of the femur escaping below the tendon of the obturator internus without rupturing the latter was recognized by Bigelow, and considered by him to determine a class of dislocations which he called "dorsal below the tendon." These are the "low dorsal dislocations of Allis" and the dislocations into the sciatic notch of Astley Cooper.

Whether after a dislocation inflammatory changes in the head of the femur and acetabulum will take place or not, will depend upon the amount of violence done to the cartilages at the time of the injury. In dislocations by simple leverage, the head and socket will probably escape without bruising, no inflammatory changes are likely to occur, and a new socket and new capsule may be formed. In dislocations attended by crushing of the cartilages, such as might result from direct violence, inflammatory changes are likely to take place, resulting in the adhesion of the head to the surrounding parts or in ankylosis. The growth of osteophytes in the torn capsule occasionally takes place, and is most likely to occur in cases where the capsule is torn, together with more or less periosteum from the acetabular rim.

The specimen shown in Fig. 330 was removed at autopsy from a case of thyroid dislocation of the hip, which had remained unreduced for years. It was the occasion of a suit for malpractice. It is preserved in the Warren Museum at the Harvard Medical School. As shown in the figure, the growth of osteophytes around the head of the femur, which was dislocated into the obturator foramen, has resulted in the formation of an almost complete new socket. Marked thickening of the neck of the femur also resulted from the same cause.[1]

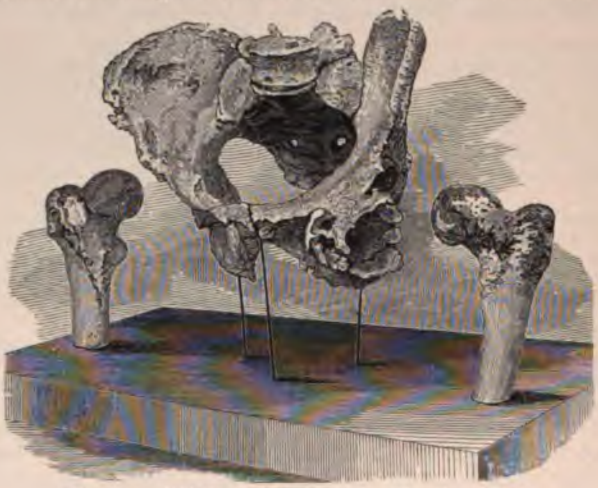


FIG. 330.—Old thyroid dislocation, with osteophytes.

Signs of Dislocation.—Dorsal or Outward Dislocation.—In this, the most common form of dislocation, the head has escaped through the posterior part of the capsule, and lies with the neck against the outer plane of the pelvis; the trochanter is thus held away from the bony pelvis and cannot be made to touch it. According to Bigelow's classical description, "the limb is moderately inverted, a little shortened, and advanced;" the toes cross the toes or the instep of the other foot, according to the degree of flexion and inversion, and the head of the bone may generally be felt upon the dorsum. The inversion is chiefly due to the tension of the outer branch of the Y-ligament, and disappears when this is divided.

When extreme flexion is present, together with greater inversion and advancement of the limb, the head of the femur, according to Bigelow, is caught below the tendon of the obturator internus, and to this dislocation he gives the name of "dorsal below the tendon."

[1] *Surgical Observations*, J. Mason Warren.

The variation in the signs according to the high or low position of the head, however, is of minor importance. The inversion, flexion, and adduction are the inevitable result of the relation of the head of the bone to the fixed pelvic wall and the tightened Y-ligament; and these, together with the palpation of the head in its abnormal position upon the dorsum under the glutei muscles, where it can almost always be felt, are the incontrovertible signs of the dorsal or outward dislocation.

Thyroid or Inward Dislocations.—In this class the characteristic position of the limb is flexion and abduction, the heel being raised from the floor and the toe pointing outward and forward. This position, which is attended by marked constraint, is due to the weight of the limb holding the great trochanter against the lower rim of the acetabulum, the tightened Y-ligament acting as a bridle and preventing complete extension. The great trochanter is thus brought into close contact with the acetabulum, lies deeply, and cannot be felt (Fig. 332).

FIG. 331.—Dorsal dislocation of the femur (Boston City Hospital, service of F. S. Watson, M.D.).

In the "low thyroid," the "dislocation near the tuberosity or perineum" of Bigelow, the limb will of necessity be more strongly flexed, in order that the tight Y-ligament may allow the low position of the head.

Bigelow's "dislocation upon the pubis" becomes under Allis's classification the high thyroid dislocation, and is simply a variety of the inward dislocation characterized by a high position of the head of the bone, and having as symptoms less marked flexion and greater shortening and eversion.

The thyroid reversed is produced from the simple thyroid dislocation by outward rotation of the leg until the head of the femur passes in front of the Y-ligament and lies in front of and below the anterior superior spine of the ilium. In this variety the foot may be everted so far that the toes point backward. This form of dislocation is rare, due to extreme violence, and usually associated with other injuries of a severe character.

Reduction.—Since the time of Hippocrates flexion of the hip-joint had been recognized as an important step in the procedures for the reduction of dislocations. The course of the characteristic deformity of these luxations, however, and the chief obstacle to their reduction, was believed to be the contraction of the powerful muscles about the hip-joint. Before the advent of anesthesia the want of a suitable means of producing muscular relaxation, and the ignorance of the manipulations suited for reduction, resulted in the substitution of great force—applied by screws, ropes, and pulleys—for properly directed manipulations. As this powerful extension, which was found necessary (as it was supposed) to tire out the contracted muscles, but in reality to rupture the Y-ligament, was most easily applied in the axis of the body, longitudinal traction by pulleys was the method taught in the English

school at the beginning of this century, of which Astley Cooper was the most prominent exponent. The blind brute force thus so cruelly applied was the cause of untold suffering and of permanent damage to many hip-joints during the period that this method was taught. Nathan Smith and William W. Reid in this country recognized the value of flexion and manipulation in the reduction of dislocations of the hip, but attributed the success of the flexion method to the fact that it relaxed the contracted muscles.

To Bigelow is due the credit of showing that the Y-ligament, and not the contraction of the muscles, was the chief agent in producing

FIG. 330.—Thyroid dislocation (Massachusetts General Hospital; service of John Homans, M.D.).

the deformity in hip-dislocations and in preventing their reduction by longitudinal traction, and that its aid must be invoked in any method for their easy and safe reduction.

Bigelow's Methods of Reduction.—In Bigelow's methods of reduction, which have stood the test of time since his Memoir was published in 1869, advantage is taken of anesthesia to produce muscular relaxation, and the positions of the patient and surgeon are such as to allow of the most advantageous application of his strength. The etherized patient lies on his back on the floor. The surgeon, standing beside the patient, grasps the ankle with one hand; while the other, placed beneath the head of the tibia, lifts and guides the limb (Fig. 331). The thigh is then flexed upon the abdomen, and, if the dislocation is dorsal, is adducted and a little inverted, to disengage the head of the bone from behind the socket. It is then forcibly lifted or jerked upward, with a little simultaneous circumduction, and the head passes into the socket. Or, the thigh is flexed upon the abdomen, and then simultaneously, in a single sweep, abducted, or circumducted and rotated outward. Bigelow describes the maneuver simply in the phrase "lift

up, bend out, roll out;" or "flex, abduct, evert." This circumductive sweep Allis has shown to be attended by danger of bruising or catching up the sciatic nerve, which his new methods of reduction have been designed to avoid.

In case the thigh cannot be abducted beyond the perpendicular, Bigelow considers that the head of the femur has emerged through a too small orifice in the capsule, which, in order to allow of its return, must be circumducted in the opposite direction. This circumduction will convert the dorsal into the thyroid dislocation, but will enlarge the capsular opening, in his opinion, so that the forcible lifting with the thigh flexed can hardly fail to effect reduction. The fallacy of the view that the head ever escapes by a slit in the capsule which requires enlargement has been pointed out earlier in this article, and the danger of injury to the sciatic nerve by the circumductive sweep has been already commented upon. Upon the tightened Y-ligament as a center, the head of the femur, with the length of the neck for a radius, is rotated below the rim of the acetabulum, and as the flexion of the thigh carries the sciatic nerve across the back of the joint, may easily catch up that nerve, especially if it be tightened by extension of the leg at the knee. This has been repeatedly demonstrated by experiment upon the cadaver, and has probably happened in actual practice.

FIG. 333.—Reduction of dislocation into the thyroid foramen (after Bigelow).

For reduction of thyroid dislocations Bigelow recommended a variety of methods. The two methods which he characterizes by the terms "rotation" and "traction" are the most typical. In the first method he flexes the limb toward the perpendicular, abducts a little to disengage the head of the bone, then rotates the thigh strongly inward, adducting it, and carrying the knee to the floor. This maneuver is practically the reverse of the flexion, abduction, and eversion employed to reduce the dorsal dislocation, and is, in fact, flexion, adduction, and inversion.

The method by traction consists in flexing the limb and drawing the thigh outward by a towel passed around its upper part, or thrusting it outward by the foot applied to the groin.

Allis's Methods.—These methods are designed to make the head return to the socket by the path by which it escaped, or to retrace the steps which produced the dislocation, without exposing the sciatic nerve or other contiguous structures to danger from the circumductive sweep of the head of the bone. In "outward dislocations" the first step—retracing the last step of the dislocation—is flexion, in addition to which it may be necessary to add traction downward to free the head from the dorsum. Next, the foot is turned outward (inward rotation), so that in the next motion—lifting—the head may not strike against the projecting acetabular rim and be arrested by it. Then the

head is lifted to the head of the socket, and often may be felt to catch on the tendon of the hamstring muscle, or the sciatic nerve, or both, as it is lifted past them. The leg is next turned inward to throw the femoral head outward into the socket, and is then brought down in extension. The passage of the head into the socket may be facilitated by direct pressure by the thumbs of an assistant.

The method may be tersely expressed as follows:

1. Flex, turn leg out, and lift.
2. Turn leg in, and extend.

For dislocations inward Allis gives two methods: 1. The Direct; and 2. The Indirect.

In the *direct method* the femur is first flexed and abducted, in order to bring the head into the position it occupied when it first left the socket; the traction outward in the long axis of the femur brings the head over the socket. Direct pressure is made by the thumbs of an assistant upon this head, and the limb adducted. In brief, the steps are:

1. Flex and abduct the femur.
2. Make traction outward.
3. Fix the head by digital pressure and adduct.

In the *indirect method* rotation is employed to carry the head into the socket.

The steps are: 1. Flex the thigh, but not to a perpendicular (this brings the head into the position it occupied when it left the socket).

2. Adduct and carry the knee obliquely downward and inward (by this movement the remnant of the capsule becomes tense and draws the head upward and outward).

3. Rotate outward—thus turning the head into the socket.

By these methods circumduction, with its attendant danger of injury to the sciatic nerve, is avoided.

After-treatment.—The after-treatment which should follow reduction is simple, no fixation apparatus being required. The patient should be kept in the dorsal recumbent position for three weeks, and the heels and the knees should be tied together in the extended position, thus taking advantage of the "hammock" function of the iliotibial band, which is stretched tightly across the great trochanter and holds the head of the femur firmly in the acetabular socket.

After three weeks massage and passive movements may be employed, and the patient, aided by crutches, may cautiously begin the use of the limb.

Complications.—**Cleaning out the Socket.**—Under the head of Pathology was discussed the danger of the capsule being caught between the head of the femur and the acetabular socket in cases where the capsule was torn off close to the rim of the acetabulum. Not merely the capsule, but shreds of torn muscle or fascia may become interposed between the head and the acetabulum. Allis has pointed out that, whether muscle or capsule, it must be attached to the pelvis, and not to the femur. If one side of the head of the femur has driven a bit of capsule before it into the socket, the opposite side must be employed to turn it out, as is evident from the accompanying diagram (Fig. 334).

That this accident has happened will be evident in practice from the fact that the leg cannot be brought quite down into position; there is slight constraint, and the motion of the femur is somewhat embarrassed. Allis recommends, if the capsule has been pushed in from the dorsal side, flexion and abduction; if from the thyroid side, flexion and adduction.

These manipulations will serve to catch the bit of capsule on the edge of the femoral head. The femur is then rotated inward to tighten

FIG. 334.—1. Capsule inverted. 2. Capsule caught. 3. Capsule everted.

the Y-ligament, and the knee raised to the median plane to push the foreign tissue out of the socket.

Entanglement of the Sciatic Nerve.—Under the headings of Mechanism and Pathology reference has been made to the danger of catching up the sciatic nerve, and it has been shown how the nerve and its accompanying hamstring muscles are stretched tightly across the back of the joint when the latter is flexed. The danger of catching the nerve across the neck in circumduction has been emphasized.

The diagnosis of this condition is made by the fact that the leg does not come down into full extension, and a tense cord, which is the stretched nerve, may be felt in the popliteal space.

It may be reduced by redislocating the femur, turning the ankle of the flexed leg outward, and attempting, by rocking and shaking, to make the nerve drop off from the femoral head, the head then rotating into place without flexing the femur. These failing, an open incision has been suggested (Allis) for freeing the nerve from its position.

Dislocation with Fracture of the Shaft.—The diagnosis may be difficult, and is made by locating the upper fragment and finding that this does not follow the rotatory movements of the shaft. In these conditions we are able to employ traction alone for purposes of reduction, leverage being evidently out of the question.

Inward dislocations may be reduced by traction outward, with direct pressure upon the head. This may be supplemented, if unsuccessful, by traction inward or obliquely inward and downward, the head being held beneath the socket by an assistant to prevent its slipping back into the thyroid depression.

Outward dislocations with fracture of the shaft may be reduced by first bringing the head to the level of the socket by traction directly upward, followed by traction upward and inward, assisted by direct pressure upon the head by an assistant's fingers.

Compound Dislocation.—This is a rare condition, the result of great violence, and usually attended by other serious injuries. The

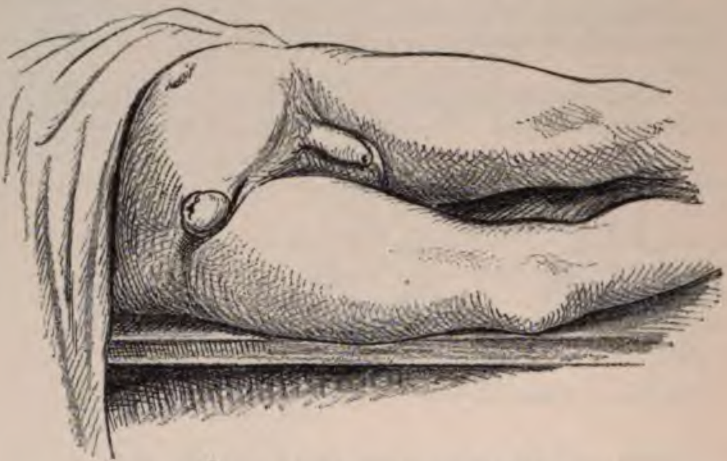


FIG. 335.—Compound dislocation of the hip (Cheever).

accompanying illustration (Fig. 335) represents a case in which resection of the femoral head was practised. Death resulted from the concomitant injuries.

CHAPTER XIX.

DISEASES OF THE BONES.

INFLAMMATION.

WHEN inflammation attacks a bone, it does not remain limited to one part of the bone. Thus, in the case of inflammation attacking the medulla of bone, or osteomyelitis, we have also inflammation of the dense structure of the bone, or osteitis, and very commonly inflammation of the periosteum, or periostitis. Conversely, if the inflammation attacks the periosteum, we have also inflammation of the dense portion of the bone. Hence from the point of view of treatment these various conditions must be considered more or less together.

Inflammation of bone may be acute or chronic. Acute inflammation of bone may be suppurative or non-suppurative. Chronic inflammation may be divided into simple chronic inflammation, tuberculous inflammation, and syphilitic inflammation.

Acute Non-suppurative Inflammation of Periosteum and Bone.—This is a very rare condition, and it is, as a matter of fact, doubtful whether a really acute inflammation can take place in these structures without suppuration. A form of periostitis has been described by Ollier under the name of *albuminous periostitis*, in which exudation occurs under the periosteum of a serous or albuminous nature; but this affection is probably only a mild or early stage of the suppurative form, and it is said that the pyogenic cocci are present in the exudation. In the case of typhoid fever, periostitis may occur, and is due either to the typhoid bacillus or to a double infection with the pyogenic organisms.

The changes that take place in the periosteum under these circumstances are essentially the same as those in acute suppurative periostitis. There are redness, swelling, and thickening of the periosteum, with effusion of fluid, followed by increase in the thickness of the bone after the acute stage of the inflammation has passed off. The symptoms are intense pain, fever not so high as in a suppurative form, and, if the bone is superficial, some redness of the skin over the part. The *treatment* is essentially the same as in the suppurative form, though in the first instance one might continue the use of fomentations for a longer period than in the case of acute suppurative periostitis.

Acute Suppurative Inflammation of Bone.—This is usually spoken of as *acute osteomyelitis*, because the inflammation almost always begins in the medulla of the bone; in a few cases, however, the deeper part of the periosteum is the primary seat of the process.

Acute suppurative osteomyelitis is an acute suppurative inflammation of the medulla of the bone, which occurs especially in young subjects, and which may be accompanied by general infection of the body. It is due to the pyogenic organisms, more especially to the Staphylococcus pyogenes aureus, and the disease may arise without any open wound in the vicinity, or after an open wound such as amputation or a compound fracture. When the disease commences without any external wound, the organisms must, of course, be deposited in the part from the blood, and to account for their presence in the blood one usually finds some preceding inflammatory condition elsewhere, such as a boil. In many

cases, apparently, the organisms gain access to the blood in connection with an intestinal catarrh, and the disease is not uncommon after cholera and acute intestinal disturbances. As to the deposit of the organisms at the particular part affected, there is very often some history of local injury. The disease occurring spontaneously almost always

FIG. 336.—Acute osteomyelitis of the tibia (Nichols).

attacks the bone in the immediate vicinity of the epiphysis, where the circulation is slower and where it has been shown that solid particles floating in the blood are very apt to be deposited, the commonest seats being the lower end of the femur, the upper end of the tibia, the upper

end of the humerus, and the lower end of the radius. Of the cancellous bones, the os calcis near the epiphyseal line is perhaps most frequently affected. In some cases the suppurative inflammation begins beneath the periosteum; but usually the suppuration under the periosteum is secondary to osteomyelitis.

The **result** of acute inflammation in the medulla of the bone is that the part becomes greatly congested, fluid is poured out which fills up the cancellous spaces and Haversian canals, and subsequently accumulates under the periosteum, the medulla very quickly becomes infiltrated with pus, the periosteum thickened and swollen, and pus also forms beneath it (Fig. 336). The suppuration under the periosteum may result without any communication with the medulla, or in some cases only after the bone has become softened at some part, and a communication is thus established.

In young children the disease may remain localized in the neighborhood of the epiphyseal cartilage, and is then spoken of as *acute epiphysitis*. This condition may very quickly lead to destruction of the cartilage, or at any rate to a solution of continuity between the epiphysis and the diaphysis. More commonly, however, a greater or less portion of the shaft also becomes involved.

If the patient lives and no surgical treatment is adopted, this condition almost always results in death of a greater or less portion of the bone, hence the term "*acute necrosis*." The part of the bone which dies is essentially the dense shaft, and it may involve the whole circumference or even the whole length of the diaphysis, or it may be limited to a small portion in the vicinity of the epiphysis; it may also involve the whole thickness of the shaft, or only a part of the central or peripheral portion. Suppuration soon occurs beneath the periosteum, and the abscess later on bursts externally, and subsequently fresh abscesses and openings may form. So long as the dead bone remains, these abscesses refuse to heal, and sinuses continue which lead down to the sequestrum. When the abscess bursts, the severity of the inflammation usually subsides, and then processes go on which lead to the separation of the dead bone.

The **symptoms** of acute osteomyelitis depend on the virulence of the causal organisms and on the extent and situation of the disease. In any case there are usually violent fever and great pain in the first instance; but the fever soon passes into the typhoid type, being accompanied by a rapid small pulse, headache, thirst, dry tongue, stupor or delirium, so that the disease is at this stage often mistaken for typhoid fever or meningitis. The pain is generally intense, and if the bone is superficial, swelling is soon apparent over it, the skin also becoming red or livid. In the course of a few days fluctuation becomes evident, and on incision pus escapes; the bone is felt to be bare in parts, while in others, though not actually bare, the periosteum peels off very readily. Where the bone is more deeply seated, or where the process is confined to the medulla, the swelling and redness may not appear so early; but in any case the pain is extremely severe, so long as the patient is sufficiently conscious to refer to it. In young children it often happens that it is only more or less accidentally that one finds a particular bone which is affected, especially where the patient is in a state of stupor. Under such circumstances the patient does not call any

special attention to the part, and it is these cases which are often so extremely difficult to diagnose. In severe cases the symptoms are very grave indeed, and may end in death in two or three days from rapid septicemia, while in others the patient may survive, and die subsequently of pyemia, septicemia, ulcerative endocarditis, exhaustion, etc. When the disease is in the neighborhood of the epiphysis, the joint in the vicinity often becomes inflamed and swollen, though not necessarily suppurating.

Prognosis.—If suppuration occurs in the joint, the prognosis is very grave. The prognosis also depends to a very great extent on the treatment; early and vigorous treatment may save even very grave cases. Under any circumstances, however, the prognosis is grave, as regards both the immediate and subsequent results, the certainty being that at the best the patient will have a long illness, that he may have serious derangement of the neighboring joint, and that deficiency in growth, often with great deformity, may result.

So far, we have been speaking of acute suppurative inflammation of bone as it arises spontaneously; but in other cases the disease may follow wounds of bones such as amputations, compound fractures, etc. Under these circumstances the infection spreads up through the medullary cavity, and also frequently under the periosteum at the same time, and the result is that if the patient lives, there is usually necrosis of the greater part of the bone, extending upward for a considerable distance along the shaft, and not infrequently small independent sequestra are found, especially toward the central part of the bone. The symptoms here are, of course, similar and equally grave, but the diagnosis is more easily made, because attention is at once directed to the part where the inflammation is taking place.

Diagnosis.—These cases of osteomyelitis and acute epiphysitis must be diagnosed from a number of other diseases, more especially from typhoid fever and meningitis, from acute rheumatism, from an abscess outside the bone, and, in the less acute forms, from non-suppurative inflammation, tuberculosis, and other diseases. As regards the diagnosis from *typhoid fever*, etc., that difficulty only arises in the very acute forms where there is rapid poisoning of the patient, and where he cannot therefore give an account of his symptoms, and more especially in young children who are not able to tell what ails them. In cases of this character, where symptoms set in so acutely and rapidly, one should suspect a septicemic condition rather than a specific fever, such as typhoid fever; and in all suspicious cases one ought to feel over the body, especially over the bones usually affected, to see whether pain is caused or not; if the child winces, a local cause is at once manifest. In the case of osteomyelitis, also, the pressure of the bone in an upward direction, such as tapping on the feet in cases of osteomyelitis of the tibia or femur, causes pain.

In *acute rheumatism* the symptoms are more general, a number of joints are affected, and on the whole the condition of the patient is not so bad as in osteomyelitis. The temperature in the first instance is not so high, nor does the patient pass into the typhoid state. A *deep-seated abscess* will rarely give rise to any great trouble. It does not usually produce the violent constitutional symptoms, especially

the typhoid state of acute osteomyelitis. When the abscess is in the leg, tapping the foot will not usually increase the pain unless the inflamed part itself is touched or moved.

The **treatment of acute suppurative inflammations of bone** must be considered according to the stage of the disease and the part of the bone which is more especially affected, according to the presence or absence of suppuration in the neighboring joints, and according to whether it has followed an open wound or not.

Acute suppurative periostitis is extremely rare; but if in a case where the symptoms have lasted for only two or three days it is found, on cutting through the periosteum, that a large abscess is present, it is possible that the disease is limited to the subperiosteal tissue, and it may be well to remain content, at any rate for twenty-four hours, with free incision through the periosteum. This incision should be extremely free, and it is well to wash out the pus in these cases. When it is possible that the medulla may not be affected, it is inadvisable to open up the bone at the time of the first operation, otherwise it might become infected and the state of matters be made very much worse; but if, after twenty-four hours, it is found that the grave symptoms still continue without relief, it is an indication that the disease was not limited to the periosteum, but affects the medulla of the bone, and therefore under these circumstances the patient should be again anesthetized, and the medulla of the bone thoroughly opened up in the manner immediately to be described.

The treatment of *acute osteomyelitis* consists in freely opening up the medullary cavity and clearing out all the pus and medullary tissue. As soon as the diagnosis has been made, a free incision should be made down to the bone, the periosteum turned to one side, and, with a chisel and hammer, the dense shell of the bone cut away till the medullary cavity has been well opened up and all the soft material thoroughly scraped out. The incision in the bone must be extended until the whole affected area of bone has been exposed; but in cases where the whole diaphysis is affected, it may be more convenient to make several openings in the bone and to scrape out the cavity between them, rather than to make one large gutter. Seeing, however, that a large portion of the bone will probably die, there is no particular harm in gouging away a large amount, for one may actually remove the whole of the necrosed portion in this way. After having thoroughly cleaned out the whole of the medullary cavity, it should be sponged with undiluted carbolic acid, and drainage-tubes inserted. A little cyanid gauze may also be introduced between the edges of the wound and between the drainage-tubes, so as to prevent closure of the wound in the first instance. The limb should be placed on a splint. If after three or four days it is found that the wound is aseptic, the stuffing may be left out, and only one or two drainage-tubes retained at the angles of the wound, the rest being stitched up.

In cases where the whole of the diaphysis is dead and separated at the epiphyseal line, it may be removed, the periosteum being left intact; and under such circumstances a certain amount of bony formation may occur from the detached periosteum, sufficient sometimes, where there are two parallel bones, to give stability to the limb. If a

sufficient amount of bone does not develop, bone-grafting must subsequently be employed; but this cannot be carried out unless the wound is aseptic. In most cases it is best to delay bone-grafting until the wound has quite healed, and then subsequently to open up the parts again with the view of introducing the grafts.

In the after-treatment one must remember the tendency of the neighboring joints to become stiff as the result of inflammation in the joints themselves, leading to adhesions and obliteration of portions of the synovial capsule, as well as of inflammatory exudation around the joint, giving rise to fibrous adhesions around it, and of adhesion of tendons to the bone. With the view of avoiding these troubles, the splint should not be continued too long, and after two or three weeks massage and passive motion of the neighboring joints and muscles should be carried out. In the case of the lower extremity, it is well to keep the patient in bed so long as there is a prospect of the wound healing; but if it is evident that a sequestrum is present, there is no particular object in keeping him in bed, and his strength will be better maintained by allowing him to get about. As regards the upper extremity, of course, the patient need not be kept in bed at all after the fever subsides.

Among the chief risks of acute osteomyelitis are septicemia and pyemia, and in spite of free and early operation some patients still succumb to these diseases. As regards pyemia, if symptoms of that disease appear, such as rigors, etc., one should examine the state of the main veins of the limb, with the view of seeing if any of them are thrombosed and can be cut off from the general circulation. In many cases, however, the septic thrombosis affects the smaller veins either in the bones or just as they leave the bones, and it is hardly possible to carry out what seems to be the only promising treatment of pyemia—viz., the removal of a portion of the vein beyond the thrombosed part and the clearing out of the clot. Hence in these cases, when pyemia declares itself, the question of amputation must be carefully considered, and if amputation can be carried out without marked shock to the patient, and above the seat of the thrombus, it gives the patient the best chance. If thrombosed veins are found in the stump, they should be followed up and removed at a point beyond the thrombosed area.

In cases of septicemia, on the other hand, there is no particular advantage in amputation, because under those circumstances the affection generally spreads beyond the region of the bone. Hence in septicemia we can only see that the suppurating part is thoroughly opened up, cleared out, and disinfected, and carry out the rest of the treatment on the lines indicated in speaking of septicemia.

In cases of *acute epiphysitis*, which especially occurs in children, the epiphyseal cartilage is very apt to be completely destroyed, and as the result no further growth of the bone takes place; thus very material shortening of the limb may result as the patient grows up. As regards the treatment of the acute stage of epiphysitis, we have nothing to add to what has been already said with regard to acute osteomyelitis generally. Free incisions must be made down to the part as soon as possible, the periosteum divided, and the bone gouged away on the diaphyseal side of the epiphysis, so as to open up the region thoroughly. The only point to which we need refer in connection with acute epiphysitis is the deficient growth of the bone afterward—a condition which is not only very serious as causing shortening of the limb, but which is particularly troublesome where one of two parallel bones is affected, leading in that case to great deformity of the foot or hand.

With the view of remedying this deformity, some surgeons have proposed that in cases of acute epiphysitis of one of two parallel bones it would be well to destroy the epiphyseal cartilage of the healthy bone. The great objection to such a procedure in the early stage is that one cannot at first be quite sure that the cartilage is entirely destroyed. Where, however, two or three years have elapsed, and it is evident that no growth is taking place, this suggestion is well worth considering. The alternative procedure is to allow the bone to grow and the deformity to take place, and then to cut down and excise portions of the longer bone, so as to bring the foot or hand straight again. The decision as to which of these procedures should be adopted depends essentially on the age of the patient when first attacked by the disease —*i. e.*, on the amount of growth which has yet to take place, and the consequent degree of deformity. If, for example, several years have to elapse from the occurrence of the disease to the completion of growth, the chances of getting a useful result from taking out a portion of the elongated bone are comparatively slight, at any rate if one waits till growth is complete, because by that time the joint-surfaces will have become altered, accommodated to the new state of matters, and will not readily take up a fresh position; and further, the tendons and muscles and other structures will all have become short in accordance with the deformity. Hence, if this method of procedure is to be carried out, it should be done long before the bone has attained its full growth, and should be repeated if necessary. Under some circumstances, however, the first plan is often the best.

Where we have *acute suppurative inflammation of bone accompanied by suppuration in the neighboring joints*, we have to do with a very serious condition, and one which often ends fatally. These are usually cases of acute epiphysitis. Under such circumstances, the first thing that one thinks of is the advisability of amputation, and in most cases, if the patient is seen before his condition has become hopeless, amputation through the bone above is the best treatment. In some cases, however, where the symptoms are not so severe, one may be content with opening up the medulla, as already described, and in addition making free incisions into the joint so as to expose thoroughly and evacuate every recess, subsequently draining the joint for a time, and if necessary employing constant irrigation.

As regards *acute suppurative osteomyelitis and periostitis resulting after an open wound*, we meet with this at all ages, and the age of the patient is of very great importance in determining the method of treatment. Under these conditions the organisms at once spread into and along the medulla and under the periosteum with great rapidity, and lead almost certainly in the case of an amputation-stump to complete necrosis of the lower end of the stump, and very often to the formation of sequestra higher up. This condition is also extremely apt to be accompanied with pyemia; and in the case of a stump the piece of bone which is left is very often not worth saving, at any rate not worth risking the patient's life to save. Hence the proper procedure in acute necrosis following amputation-wounds seems to be early amputation through the joint above.

In the cases of compound fractures where osteomyelitis has set in,

unless the condition is very limited, amputation is usually the best practice; but in some cases where the disease is quite limited and the patient is young, one may delay and wait for the separation of sequestra, and in this way get a satisfactory limb.

Necrosis of bone follows acute suppurative osteomyelitis and periostitis, and may also result from tuberculous disease, syphilis, the action of phosphorus, etc., Here we shall only consider the *sequestra* which follow acute suppurative osteomyelitis. In this case the sequestra present the character of the normal dense bone, which dies before any alteration has taken place in it. Once a piece of bone has died, it must become separated from the living by a process of granulation and suppuration; the living bone in the immediate vicinity of the dead gradually becomes soft as the result of rarefying osteitis, and ultimately the solid part of the bone disappears and its place is taken by granulation-tissue. When once the whole of the living bone in immediate contact with the dead has been converted into granulation-tissue, suppuration takes place at the point of contact, and then the piece of dead bone comes to be loose, lying in a cavity lined with granulation-tissue. The time required for the separation of the dead piece of bone varies from six weeks to six months, according to the density and vitality of the bone affected. During the process of separation of the dead bone, condensation of the bone around takes place, and new-formation of bone goes on actively from the periosteum, which has been detached, and from the surface of the bone at the point of junction of the living and the dead. Hence, while the sequestrum is becoming loose, new bone is being formed extensively around it, till by the time the sequestrum is detached it lies in a cavity formed partly of new bone, two or three holes termed cloacæ being left in the new case, through which the pus escapes. The dead fragment, if of any size, cannot escape through the holes that are left in the bony case, and, although small portions may become broken off and gradually work their way to the surface, the main sequestrum lies there unless it is removed by artificial means. So long as it remains, suppuration is kept up around it; the inflammatory condition of the bone continues, there is steadily increasing condensation of the bone, and steadily increasing thickness of the bony case which covers it. In the flat bones, however, such as the skull, the production of new bone is not nearly so marked, and there is very seldom anything like complete enclosure of the dead fragment in a bony cavity.

The **symptoms** indicative of the presence of dead bone are, in the first instance, a previous history of [illegible]

though we may not be able to find bare bone, it is certain to be there under the circumstances mentioned, and the failure to find it simply means that the sinus is tortuous or that the opening in the new case is too small to admit the probe.

Treatment.—During the period which intervenes between the attack of acute illness and the separation of the sequestrum, there is no object in any surgical interference; for if one cuts down at that time, it is difficult to be certain how much of the bone is dead and where the point of contact of the dead and the living is. Therefore, up to the time when the bone has become separated by natural processes, all that one need do is to apply antiseptic ointments to the orifice of the sinuses and to see that proper escape of discharge is provided. When a suitable time for operation has arrived, the first point for consideration is how we can get as free access to the dead bone as possible; and if the sinuses are situated in parts where, on account of the presence of nerves, vessels, etc., we cannot make a free enough opening, we should disregard the sinuses altogether and cut down on some other part of the bone where the anatomical arrangements are more favorable. The incision in the skin should be coextensive with the thickening of the bone, because it is absolutely essential that the whole cavity in which the bone lies should be freely opened up, both with the view of making certain that the whole fragment is removed, and also with the view of providing proper escape of discharge afterward and of obtaining proper closure of the cavity. The skin and tissues are therefore divided freely, the periosteum detached laterally over the thickened area, so as to give free access, and then with a chisel and hammer one proceeds to chisel away the bone till one reaches the cavity where the sequestrum is present. Where the patient is weakly, it is in most cases advisable to apply a tourniquet before the operation, both with the view of preventing unnecessary loss of blood, and also with the view of being able to disinfect the cavity thoroughly afterward. Having reached the cavity in the bone, it should be opened up completely from end to end and from side to side till the sequestrum can be lifted out without any trouble. Having removed the sequestrum and thoroughly scraped out all the granulation-tissue, one should also dissect out the sinuses which lead to the diseased bone, and then proceed to disinfect the parts in the hope of obtaining asepsis. The part should be thoroughly sponged with undiluted carbolic acid, and after this has acted for a few minutes, the cavity should be tightly packed with gauze sprinkled with iodoform. The tourniquet can then be relaxed, and any superficial vessels which spout can be tied and the rest of the wound filled up with packing. An antiseptic dressing is applied outside, and in many cases one in this way succeeds in rendering the wound aseptic.

An important point in the after-treatment is to decide what is to be done as regards the large cavity left behind. If the septic condition is not eradicated, the stuffing can be taken out in two or three days, and the best thing to do then is to stitch together the skin-incision, with the exception of an opening at one end through which a large drainage-tube passes into the cavity. When we find on dressing the wound after three or four days that there is no suppuration whatever, the stuff-

ing should be completely removed, and an attempt may be made to fill up the cavity with material which will become organized, either blood-clot alone, or catgut, or decalcified bone-chips. Of these methods, the best is bone-grafting by means of decalcified bone-chips. These bone-chips are decalcified and kept in a solution of corrosive sublimate in alcohol. The cavity is filled up with the bone-chips, a little bleeding is induced, so that the intervals between the chips become filled with blood-clot, and then the periosteum, if possible, is brought together, a stitch or two put in between the muscles, and the skin-wound closed. A drainage-tube is not usually required unless excessive bleeding is present, in which case a few strands of catgut brought out at the lower end of the wound will allow the superfluous blood to escape. The wound is covered with an antiseptic dressing, and the part placed at rest on a splint.

As regards the after-treatment of operations for necrosis, one must remember that if the limb is kept at rest too long, not only may the neighboring joints become stiff, but the muscles are very apt to become adherent to the edge of the opening in the bone, and also to become thickened and matted together. Therefore, from quite an early period massage should be employed. This, however, must be more carefully done in cases where bone-grafting has been employed, otherwise the young organizing material may be broken up and organization prevented. At the same time it should be remembered that the patient has been pulled down by the previous illness, and nourishing diet and the best hygienic conditions employed. The administration of iron, especially in the form of Blaud's pills or capsules, is of importance; the condition of the urine must, of course, be watched, and so on. While this is the general rule of treatment in young persons, in old people amputation is frequently advisable, and it may also be required in young persons where the health is much broken down, the kidneys diseased, etc.

Sir James Paget has referred under the name of "*quiet necrosis*" to a condition in which necrosis of bone occurs without any violent inflammation and without the formation of sinuses leading to the sequestrum. These cases are rare, and it is probable that a good many of them are examples of tuberculous disease of bone. Cases are seen, however, and I have met with them, where on chiselling up a mass of inflamed bone a sequestrum is found in the interior; but the only interest in these cases, from the point of view of treatment, is to remember that when one is opening up bone thickened as the result of chronic inflammation, one should be on the lookout not only for a chronic abscess, but also for a piece of dead bone.

Chronic Periostitis and Osteomyelitis.—In addition to the acute forms of inflammation of bone, we may have inflammation of a more chronic type affecting either the periosteum or the medulla and adjacent dense bone. This condition may in some cases follow the acute, but more usually it is chronic from the first. In the case of chronic periostitis the result is great thickening of the periosteum itself and marked formation of new bone underneath it, and also great condensation of the pre-existing bone. In the case of chronic osteomyelitis the result is either softening of the bone, "rarefying osteitis" or condensation of the bone, "condensing osteitis," or a localized abscess in the bone, "Brodie's abscess." In some rare cases, as has just been mentioned, a sequestrum has also been found.

As to the **etiology** of chronic periostitis and osteomyelitis, it sometimes occurs after an injury, in other cases in connection with some con-

stitutional condition, such as rheumatism, or again under circumstances which we do not exactly understand. We exclude here chronic inflammation dependent on tuberculosis or syphilis.

As regards the **symptoms** of chronic periostitis and osteomyelitis, we have very marked thickening of the bone in the region of the disease, and tenderness over the inflamed part, generally acute at certain points. There is often a great deal of pain, which is worse when the limb becomes warm, and more especially when the patient is in bed at night. The tenderness is usually more marked in chronic periostitis than in chronic osteomyelitis; while, on the other hand, in chronic osteomyelitis the pain is more marked than the tenderness, and is especially of a neuralgic and throbbing character. In both cases the symptoms may subside at times and again get worse, the course being marked by exacerbations and remissions; sometimes even for months the patient may be comparatively free from pain, and then again suffer from a severe attack. In cases where we have Brodie's abscess of bone, the disease is generally in the neighborhood of the epiphysis, there is marked enlargement at the part, the pain is of a very intense character, especially at night, and there is generally a tender spot somewhere or other. Sometimes, indeed, where the disease has lasted long and where the bone has become softened, we may also find a soft spot.

The **treatment** of these conditions is either palliative or radical. Palliative treatment consists in rest to the part, elevation, the employment of counterirritation in the form of either blisters or the actual cautery, especially Corrigan's cautery, and the administration of drugs internally, of which the chief are potassium iodid and salicin or sodium salicylate. Apart from the possible syphilitic origin of some of these cases, large doses of potassium iodid seem to relieve the pain in some cases very markedly—doses, for instance, commencing with 10 grains three times a day, and rapidly going up to 20 or 30 grains. The result of this palliative treatment is usually, however, only temporary, and it is but seldom that a cure results, even though the treatment be continued for many months. As a rule, the patient's condition improves for a time, and he may keep pretty well while taking large doses of potassium iodid; but if he begins to walk about, and especially if he leaves off his iodid, the old symptoms are extremely apt to recur.

Hence in cases where a sufficient trial has been given to palliative measures without much benefit, it is advisable to propose an operation. The operative procedures consist in cutting down on the inflamed part and removing as far as possible the whole of the thickened and inflamed periosteum, gouging away a large portion of the thickened bone, and looking for the presence of an abscess or sequestrum or other cause. Strict asepsis is imperative. If an abscess-cavity is found, it should be thoroughly opened up in the manner described in speaking of sequestra; it is well to sponge out the cavity afterward with undiluted carbolic acid. After the operation the wound should be stitched up closely and healing by first intention aimed at. With the view of getting a better scar, one should use curved incisions, turning aside a flap, rather than a straight incision over the center of the inflamed area. Afterward the limb should be put in a splint for two or three weeks, because the cavity in the bone fills with blood-clot which must become organized.

In cases where the inflammation is at some distance from a joint, this splint may be continued even longer. When the splint is left off, the patient should still be kept in bed, if it is the lower extremity which is the seat of the disease, for six weeks or a couple of months, so as to allow the new tissue to become thoroughly firm. If the patient gets up too early, the young vessels in the organizing blood-clot give way, hemorrhage takes place, and the process of organization is apt to be arrested. Massage and passive movement should be kept up from an early period after the operation.

TUBERCULOUS DISEASE OF BONE.

The parts of the bone affected with tuberculous disease are chiefly the cancellous ends (Fig. 337), either the epiphysis itself or the shaft

FIG. 337.—Miliary tubercle of bone; on the right, beginning separation of sequestrum.

outside the epiphyseal line. In other cases, however, the medulla of the shaft may become affected, or again the disease may begin beneath the periosteum. The disease may assume the following forms:

1. **Acute Tuberculosis of Bone.**—This may occur in the course of a general acute tuberculosis, or may be limited to one bone, arising in connection with a tuberculous deposit at one part of the bone. The form which occurs in acute general tuberculosis is not of clinical importance; but where the outbreak is limited to one bone, it influences the treatment in so far that nothing short of removal of the affected bone is likely to do any good.

2. **Limited deposits of tuberculous material** may occur in bones, especially in the epiphysis or in the diaphysis in the immediate neighborhood of the epiphysis. They may present the form of soft caseat-

ing deposits in which the trabeculæ of the bone have more or less completely disappeared, or of sequestra which lie embedded in tuberculous material, and which are denser and heavier than the normal bone, but easily broken up and very slow in separating.

3. **Tuberculous osteomyelitis**, where the medullary tissue of the bone becomes infiltrated with tuberculous material. This condition especially affects the short long bones, such as the phalanges and metacarpal bones; and in the fingers it is known as "*strumous dactylitis*." It is also the most common form of tuberculosis in the small cancellous bones.

4. **Tuberculous periostitis**, in which the tuberculous material is deposited beneath the periosteum. This form especially occurs in connection with the ribs and the vertebræ, and the result of the disease is that the bone becomes eroded, and in the case of the ribs may be almost completely destroyed, and undergo fracture. At the same time the tuberculous material is apt to spread outward and form abscesses in the soft tissues.

As regards the further history of the tuberculous deposits in bone, the tendency is for the disease to spread; softening of the bone occurs, and by and by the deposit reaches the surface. In cases where the epiphysis is affected, the opening on the surface may occur either into the joint itself, in which case it is followed by acute disease of the joint, or outside the limits of the synovial membrane. The cases in which the deposit reaches the joint (Fig. 338) is discussed under the head of Tuberculous Disease of Joints (p. 703). When it reaches the surface outside the capsule of the joint, it leads to infection of the periosteum and subsequently of the soft tissues, and to the formation of a chronic abscess, which, when opened, is found to lead down to an opening in the bone, and through this opening to the tuberculous deposit in the bone.

FIG. 338.—Tuberculous disease of the knee-joint with ankylosis.

As regards the **etiology** of these cases, the ultimate cause is the tubercle bacillus, but the localization of the disease in a bone is very often brought about by the occurrence of some slight injury. These cases

occur especially in children and young adults, the tendency to tuberculous deposits in the bone being greater in children, while in adults tuberculous periostitis is more common.

The **symptoms** of tuberculous disease of bone are in the early stage often very obscure; indeed, the disease may have advanced to a considerable extent before the patient's attention is attracted to it. In the case of **tuberculous deposits toward the ends of bones,** the patient may, for weeks preceding the occurrence of any marked symptoms, have noticed an indefinite aching, or even only a feeling of tiredness, in the limb, and a disinclination to go about as much as usual, but no acute pain. Later on, some enlargement of the affected portion of the bone occurs, and the aching becomes somewhat more marked, but it in no way resembles the pain and aching which are characteristic of a simple chronic osteomyelitis or periostitis. On examining the part, some enlargement of the bone, usually limited to one side, may be found, and possibly also a little tenderness on pressure. If the disease has existed for some time, one may come across a point where the tenderness is more marked and where a certain amount of softening can be felt. If that is the case, it indicates the point where the tuberculous deposit is making its way out of the bone. When chronic abscess has formed outside a bone, accompanied by enlargement of the bone and preceded by these indefinite symptoms, the diagnosis is at once clear, because the occurrence of a chronic abscess in connection with bony enlargements is practically pathognomonic of tuberculosis. Under no other circumstances that I know of does chronic abscess occur, unless possibly in actinomycosis. Where the case is one of tuberculous periostitis, the diagnosis is generally made much sooner, on account of the early formation of a chronic abscess.

In the case of **tuberculous osteomyelitis** of the short long bones, such as the phalanges, the appearance is very characteristic. The patient is almost always a child; very often several bones are affected, and the enlargement of the bone is of a spindle-shaped character. In the early stage there is no softening or pain, and later on the presence of an abscess adds to the certainty of the diagnosis. In this case the only difficulty will arise in connection with hereditary syphilis, because in syphilis one meets with a somewhat similar condition. There, however, the condition arises usually in infancy, other symptoms of syphilis are present, and abscess-formation does not occur. In the case of tuberculous osteomyelitis of the cancellous bones, such as the tarsal bones, beyond the feeling of uneasiness and aching in the early stage, the patient does not usually notice anything till the disease has attacked the neighboring joints. The symptoms of disease of the tarsus will therefore be left till the discussion of Tuberculous Diseases of Joints.

As regards the **treatment,** it will hardly be necessary to treat separately of tuberculous deposits, tuberculous osteomyelitis, and tuberculous periostitis. The most convenient way is to speak of tuberculous disease of bone without abscess, tuberculous disease of bone with abscess, and tuberculous disease of bone with septic sinuses.

1. **Tuberculous Disease without Abscess.**—Where there is no abscess the difficulty is to diagnose the existence of tuberculous disease; but having decided that this is present, the question lies between

palliative and radical measures. Under palliative measures we include rest to the part, counterirritation, pressure, good hygienic conditions, country air, cod-liver oil, syrup of iodid of iron, etc. In the first instance, while one is still doubtful as to the existence of a tuberculous deposit, or as to whether the disease is quiescent or active, these are the measures that should be employed.

When on a careful trial of palliative measures it is found that the enlargement is increasing, and more especially when this enlargement is in the neighborhood of the joint, the time has arrived for the consideration of operative measures. The operative measures consist in turning aside a flap so as to expose the enlarged portion of bone, chiselling through the hard shell of the bone, and cleaning out the cancellous tissue till the tuberculous deposit is reached. When this is found, it should be thoroughly removed, preferably by Barker's flushing spoons or gouges. When the soft tissue or sequestrum has been scooped out, some of the hard bone in the immediate vicinity should be taken away, so as to ensure as far as possible the removal of all the tuberculous material. Having thoroughly cleared out the deposit, it is well to sponge the interior of the cavity in the bone with undiluted carbolic acid, in order, if possible, to destroy any tuberculous tissue which may still remain. The wound may then be stitched up without drainage. The carbolic acid does not seem to interfere materially with the proper formation of the blood-clot. If, however, there is much oozing, it is well to introduce at one angle of the wound for two or three days either a small drainage-tube or a few strands of horse-hair or catgut, so as to allow the blood to escape. The operation must be done with strict aseptic precautions, and an antiseptic dressing applied afterward. As regards the subsequent treatment, it is well to place the part in a splint for a time, in order to prevent movement and favor the organization of the blood-clot. Of course, the various constitutional means that have been mentioned with the view of improving the health of the patient should also be used.

The treatment is similar in cases of tuberculous osteomyelitis affecting the shafts of bones. For example, in strumous dactylitis we should persevere for a very considerable time with careful rest and pressure and good hygienic conditions. Operation is hardly necessary in these cases unless there are signs of abscess-formation outside the bone. The operation consists in clearing out the disease and thorough disinfection of the cavity in the manner just described.

In the case of tuberculous osteomyelitis of the small cancellous bones, such as the tarsal bones, the best result is obtained by excising the affected bone completely. As a rule, if only one bone is taken away, the result is extremely satisfactory as regards the usefulness of the foot. In after years, in the case of the cuneiforms more especially, one is often unable to tell that anything had been removed from the foot.

In cases where one cannot remove the whole of the tuberculous material satisfactorily, it is better not to close the wound, but to stuff it with gauze sprinkled with iodoform, and to continue the stuffing of the wound till the whole cavity has become filled with healthy granulations. When once this is the case, the stuffing may be abandoned,

the edges of the skin refreshed and brought together, and a small drainage-tube inserted for a few days to allow the escape of any fluid. If in such a case the wound were stitched up in the first instance, the blood-clot might become infected with tuberculous material, and the disease would recur.

2. **Tuberculous Disease of Bone with Abscess.**—Here the treatment is practically the same as before, with the exception that one should remove the abscess-wall as thoroughly as possible, and also that one need not delay at all with palliative measures. In the case of tuberculous disease toward the ends of bones, with chronic abscess, one should cut down on the part and dissect out the abscess as if it were a cyst, and then look for a hole in the bone, enlarge it thoroughly, and deal with the tuberculous deposit in the interior in the manner just described. In cases where we have to do with a bone like the rib, the treatment can be very satisfactorily carried out by removing the whole of the affected portion of the bone. In this case the surgeon first separates the abscess from the surrounding parts without opening it, ascertains which rib is affected and the extent of the disease, divides the healthy rib on each side of the affected part, raises it from the pleura beneath, and removes it along with the abscess. As the abscess extends to the under surface of the rib, the tuberculous material on the surface of the pleura must be carefully scraped away. The wound is then stitched up, and healing by first intention usually occurs without any trouble.

In some cases the abscess in connection with tuberculous bone-disease is very large and cannot be satisfactorily dissected out. Under such circumstances one must lay open the abscess-cavity very freely, and dissect away as much as possible of the wall. The remainder should be thoroughly scraped, and, if possible, the deposit in the bone sought for and removed. In some cases, in spinal disease for example, one cannot carry out this method of treatment, and all that can be done is to make a small opening into the abscess-cavity, wash out the contents of the abscess, scrape away as much of the wall as possible, and then, the abscess-cavity having been thoroughly cleaned out, inject some sterilized iodoform-and-glycerin emulsion, and stitch up the wound. The result is usually very satisfactory in cases where we have to do with tuberculous periostitis; but in cases where there is a tuberculous deposit in the vertebræ, the abscess-cavity is apt to refill. Even if it does, repetition of the operation on two or three occasions will very often lead to satisfactory closure of the abscess, and if followed by suitable fixation of the spine, to ultimate cure of the disease.

3. **Tuberculous Disease of Bone with Septic Sinuses.**—We have to consider the cases of tuberculous disease of bone where abscesses have formed and burst, and where the patient comes under observation with septic sinuses leading down to the diseased bone. Here again the treatment should be operative in the case of the extremities and accessible parts, because these cases with septic sinuses have but little tendency to heal. In such a case one must excise the sinuses, expose freely the part of the bone to which they lead, and attempt to remove the tuberculous portion of bone. It is of great importance, if possible, to render the wound aseptic, because the subsequent progress of the

case depends to a very great extent on that precaution. Hence the skin should be thoroughly disinfected, and, before commencing the operation, it is well to scrape away the granulation-tissue at the orifice of the sinuses and to introduce into it and leave in place a little piece of sponge soaked in undiluted carbolic acid. A long incision is then made, sufficient to expose the part, the orifices of the sinuses being enclosed in elliptical incisions. Great care should be taken, in dissecting down to the bone, to avoid cutting into the sinuses; when the bone is reached, these sinuses should be cut away. The tuberculous deposit is then dealt with in the manner already described, and the cavity left should be thoroughly sponged out with undiluted carbolic acid. In these cases one can never be sure that one has got rid of the sepsis, and therefore it is well not to stitch up the wound in the first instance. It is best to introduce strips of cyanid gauze sprinkled with iodoform into the cavity in the bone. These require renewal every two or three days, according to the amount of discharge. Very soon, if the tuberculous disease is completely removed, granulation takes place, and once the whole part has been completely covered with healthy granulations, the edges of the skin may be freshened, detached, and brought together, a drainage-tube being left in at one end to allow the escape of any discharge.

In the case of sinuses leading to inaccessible bones, such as the spine, comparatively little can be done. Our chief reliance must be placed on good hygienic conditions, on fixation of the part, and, if there is an imperfect opening, enlargement and scraping of the sinus. There is, however, very little use in these cases in subjecting the patient to elaborate operations with the view of scraping out the sinuses, for one can seldom get rid of the sepsis. The question of amputation which arises in some of these cases of bone-disease, especially with septic sinuses, has chiefly to be considered in connection with diseases of joints.

SYPHILIS OF BONE.

Syphilitic diseases of bone may occur either in the secondary or the tertiary period of acquired syphilis; they are also very common in inherited syphilis. In the secondary stage of syphilis, at quite an early period one may meet with pains in the bones without any enlargement or apparent lesion of the bone. These pains are of a rheumatic character, sometimes severe, and usually occur in connection with the early skin-eruptions. They probably imply a merely congestive condition of the bone, since they do not leave any permanent lesion. This condition generally disappears rapidly when the patient is brought under the influence of mercury.

At a later period of syphilis, however, from the sixth month onward, one meets with definite lesions of the bone, more especially in the shape of syphilitic periostitis. This condition, if neglected, leads to the formation of bony nodes. The bones affected are chiefly the more superficial ones, such as the skull, especially the frontal bones, the ribs, the sternum, the tibia, and the clavicle.

The **symptoms** to which this condition gives rise are nocturnal pains, especially when the patient gets warm in bed, and swelling of the

part with considerable tenderness, the swelling being limited in extent, but shading off into the surrounding bones and not terminating abruptly. The periosteum becomes thickened; effusion occurs between it and the bone, leading to the formation of a gelatinous material. If the condition is not treated, ossification takes place in the deeper layers of the periosteum, and a permanent mass of bone is formed, which is termed a syphilitic node. If, however, the ordinary treatment of secondary syphilis is employed at once, the thickening may disappear entirely. Hence the treatment for syphilis (see chapter on Syphilis) should be at once employed, and the patient should be quickly brought under the influence of mercury. As regards local treatment, it is well to keep the part at rest, and if there is much pain to apply evaporating lotions or fomentations. Absorption is expedited by the local use of mercurial ointment.

Gummatous Disease of Bone.—In the tertiary stage of syphilis we meet with gummata of bone, and also with syphilitic osteitis accompanied with great thickening of the bone. The gummata of bone may occur subperiosteally or in the medulla, most usually subperiosteally, and may form either circumscribed masses or a diffuse infiltration of the bone or periosteum. These gummata of bone occur most frequently on superficial bones, such as the skull, especially the frontal bones, where they begin either under the periosteum or in the diploë, the clavicle, the tibia, and not uncommonly about the epiphyseal ends of bones. The gummatous material spreads from the deeper part of the periosteum into and along the Haversian canals, and leads to rarefying osteitis in the vicinity, while condensation of the bone takes place beyond. Hence a bone which has been the seat of syphilitic gummatous disease presents an eroded and worm-eaten appearance, while the bone beyond is very dense. This condition is sometimes spoken of as *syphilitic caries of bone*, and great destruction of bone may result. In some instances portions of the affected bone may subsequently die, and a *syphilitic sequestrum* is formed. The characteristic of a syphilitic sequestrum is that it is much denser than normal bone, and that the surface is worm-eaten, due to the gummatous material spreading in along the Haversian canals and enlarging them. These sequestra, also, like tuberculous sequestra, often take a long time to become loose. In connection with syphilitic sequestra of bone, there is not the same stalactitic formation of bone around or new-formation from the periosteum as in ordinary necrosis, though sometimes, where the sequestrum is central, it may be more or less surrounded by bone.

As regards the **symptoms** of gummatous disease of bone, there may be a good deal of pain, which is generally more intense than in the case of the syphilitic node, of a boring character, and worse at night; there is a soft enlargement over the bone, adherent to it, and a previous history of syphilis. The gummata do not remain limited to the periosteum of the bone, but gradually spread toward the skin; and ultimately ulceration occurs over them, and then we have a typical syphilitic ulcer of the skin, with carious bone at the bottom.

The **treatment** of gummatous disease of bone is that of tertiary syphilis, and consists essentially in the administration of large doses of potassium iodid and mercury; the potassium iodid must be given in

large doses, and, as a rule, one should increase the dose quickly to 30 or 40 grains three times a day. This is one of the forms of tertiary syphilis in which surgical intervention for the purpose of removing the diseased bone shortens the course of the disease very much, and may, indeed, be the only means of obtaining a permanent cure. In the case of *syphilitic sequestra* in bone, the sequestra remain for years without any tendency to separate, in spite of vigorous antisyphilitic treatment, and unless their separation is expedited, the wound may never close. The surgical intervention consists in opening up the part and scraping away the diseased tissue, or, where it is very dense, chiselling away some of the dense bone. If a sequestrum is present, it should, of course, be removed. At the same time the constitutional treatment should be vigorously pushed.

In **hereditary syphilis** the changes in bone are of great interest. One of the earliest is inflammation of the epiphyses of the long bones, more especially the tibia, the humerus, the femur, and the ulna. This affection is often symmetrical, and most usually affects the diaphysis in the immediate neighborhood of the epiphyseal line, the condition often going by the name of "osteochondritis." It generally occurs during quite an early period of life, and at the neighborhood of the epiphyseal line the bone becomes very much thickened, and a tender swelling appears, forming a collar around the end of the bone at the epiphyseal line. This collar is due to marked enlargement of the cartilage, bone, and periosteum in that part. In some cases, where the disease is neglected, the condition may go on to separation of the epiphysis and destruction of the epiphyseal line.

The **symptoms** to which this condition gives rise are usually pain in the part; in fact, what the mother notices in the first instance is that the child does not seem to use the arm at all, and that it cries when the limb is moved. On examination one finds a collar-like enlargement of the end of the bone, very often symmetrical, and other signs of syphilis.

During the first year of life also there is a tendency in hereditary syphilis to the production of bosses of spongy bone on the skull, especially near the sutures, the condition sometimes resulting in the formation of four bosses around the anterior fontanel, one in connection with each of the bones, or in enlargements along the coronal suture, giving rise to what is known as the "natiform" skull. At a later period of hereditary syphilis we have gummatous changes in the bone, just like those which occur in adults, destruction of the nasal bones, of the palate, and of other bones.

As regards the **treatment** of hereditary syphilis of bone, in the early stage mercurial treatment is the best, as described in the chapter on Syphilis. In the later stages potassium iodid combined with mercury is the proper treatment.

Phosphorus Necrosis.—The effect of phosphorus on the bones is often very marked, the form of phosphorus which produces the disease being yellow phosphorus, not red, and it is practically always the lower jaw which is affected. The result of the action of the phosphorus is that the gums become ulcerated, and the inflammatory condition soon extends to the periosteum and the bone. Periostitis sets in, beginning

at the alveolar margin, and leading to the formation of large spongy outgrowths from the bone. Following this the gum becomes sore and more separated, fetid pus is constantly poured out, and a large portion of the jaw becomes diseased. Subsequently, the piece of jaw which has become affected may die, and, in fact, the whole or the greater part of the lower jaw may completely necrose. The phosphorus sequestrum, therefore, is not a piece of normal bone, but consists of the original bone with large spongy osteophytic growths on the surface. The condition of the patient is a very serious one, and he may die of septicemia or pyemia.

As regards the **treatment**, the first essential is to remove the patient from his employment, or at any rate to put him to work with red phosphorus instead of yellow phosphorus. He should also be instructed to wash his hands very thoroughly before food, because it is probable that a good deal of the trouble is due to particles of phosphorus taken in with the food, rather than to the vapor of phosphorus; and, further, his gums and teeth should be carefully watched, and at the first sign of ulceration he should give up his work and use antiseptic washes, such as sanitas and Condy's fluid. Where the disease is once established, there are two alternatives as regards treatment—either to wait for the separation of the necrosed fragment, or to excise the affected part of the jaw at once, leaving as far as possible the osteogenetic layer of the periosteum. The latter is by far the most satisfactory treatment.

RICKETS.

Rickets may be defined as a disease of the period of growth, associated with general disturbance of nutrition, and characterized by alterations in the bony tissues, deformities of the skeleton, and various internal disorders. Rickets usually occurs during early life; but in some cases children are born with rickets—so-called fetal rickets—and, on the other hand, the rickety deformities may not occur till toward the age of puberty.

As regards the **etiology** of rickets many theories have been propounded. The two which seem to be most in favor are that it is due either to injudicious feeding during infancy or to imperfect oxygenation of the blood. Probably both these views have a certain element of truth in them. According to the first view, the disease is more especially due to too early weaning of the child or to too much farinaceous food during the first year of life. The other view is that, as the result of confinement in close rooms, the blood is imperfectly oxygenated, and that carbonic acid accumulates in the blood and causes the irritating effects.

Symptoms.—As regards the effects of the disease, certain general disturbances usually precede the occurrence of the deformities. The patient is subject to diarrhea and constipation; the abdomen is tumid and sometimes tender; there is an excess of phosphates in the urine, profuse sweating about the head, especially at night while the child is asleep, delayed closure of the fontanels (which may not have completely closed up even at two years of age), delayed dentition, delay in walking, great tendency to bronchitis, the occurrence of laryngismus

stridulus, and so on. From a surgical point of view we have to do essentially with the diseases of the bones, and these manifest themselves either in enlargements about the epiphyseal lines or in curvature of the bones. Enlargement in the neighborhood of the epiphyseal lines always occurs to a greater or less degree in rickets. Curvature of the bones depends on mechanical causes, and may not be marked.

On making a section through the end of the bone, one sees that instead of the two sides of the epiphyseal cartilage being parallel to each other, that next the diaphysis is quite irregular, there are islets of cartilage extending into the bone, the epiphyseal line is very much thickened, and the ossification is very irregular. The result is that at the epiphyseal lines one can feel a distinct enlargement, and this is especially marked in such bones as the radius, the lower end of the tibia, the ribs, etc.; various bones are also altered in shape. For example, the head of a rickety patient is generally larger, higher, and narrower anteroposteriorly than normal; or it may be flattened laterally and elongated anteroposteriorly. The frontal and parietal bones are enlarged; the sutures and fontanels are slow in closing; the skull may be soft and parchment-like—a condition known as "craniotabes." Dentition is delayed for as much as six months or a year; the teeth may be irregular and imperfect; the hard palate is much arched; the alveolar border of the upper jaw is thrown forward, that of the lower jaw inward, and consequently the teeth do not meet. In the thorax enlargements are found along the line of junction of the costal cartilage and the ribs, forming the so-called rickety rosary; and in cases where there has been any obstruction to expiration, as in children who have suffered from bronchitis or broncho-pneumonia, there is generally the deformity known as pigeon-breast. The sternum stands forward, the cartilages run forward toward the sternum, and at the point of juncture of the ribs and cartilages there is a deep groove. In rickets also the chest may be constricted transversely, the lower ribs being turned outward—attributed by some to increased size in the abdominal contents, such as flatulent distention of the intestines, enlargement of the liver and spleen, etc. The spine is not uncommonly curved, usually a general anteroposterior curvature, although in some cases, in older children, the curvature may be lateral. The pelvis may be flattened anteroposteriorly, or the acetabular portions may be pushed in and the pelvis assume the shape of an ace of hearts. Very often it does not develop properly, and remains small through life. The bones of the extremities become enlarged at the epiphyseal lines, and in addition there is also a certain amount of bending of the bone, the natural curves being increased if the patient bears weight on the soft bones. The femur becomes curved anteroposteriorly, and the tibia most commonly flattened laterally and curved outward. Genu valgum is also not uncommon in rickets, and is frequently met with in adolescent rickets. Further, the rickety bones are very soft, and are very liable to undergo green-stick fracture.

The changes in the bones consist essentially in excessive preparation for the formation of new bone and imperfect deposit of the hard bony structure. Hence, in addition to the changes in the epiphyseal line already noticed, the periosteum is very much thickened, and the soft tissue in the Haversian canals and lining the medullary spaces is also greatly increased in amount. Thus the amount of dense bone is less than normal, and the bones are soft and easily bent when subjected to pressure. If a rickety bone in the acute stage of

rickets is macerated, it presents a worm-eaten appearance on the surface, due to the enlargement of the Haversian canals. When the condition of rickets passes off, bone is formed in connection with this soft material, and the consequence is that the bones become much harder and denser, and are sometimes very difficult to cut.

As regards the **treatment** of rickets, attention should be paid to the feeding of the child and to the hygienic conditions. In the first place, farinaceous food should be avoided during the first year of life, at any rate during the first nine months. The patient's diet should consist entirely of milk—if possible, mother's milk or that of a wet nurse. When the child is about nine months old, oatmeal and various prepared foods may be mixed with the milk, but it should be done very carefully, and the essential diet should still consist of milk. When about a year old, one may begin with meat-juice, an egg once or twice a week, a little gravy and potatoes, or gravy and bread. The child cannot, of course, take solid animal food until toward the end of the second year. The patient should also be placed under good hygienic conditions, should be warmly clad with flannel next to the skin, and care taken to avoid catching cold; it should be out in the air as much as possible, and especially in the sun, and if it can be managed, should be sent to the sea-side or some country place. As regards drugs, the only two which seem to be of any special avail are cod-liver oil and phosphorus. Cod-liver oil should always be given in cases of rickets, even although the children seem to be well-nourished. Phosphorus is also very useful, the dose being $\frac{1}{100}$ grain, and it is conveniently given mixed with the cod-liver oil.

If possible, the patient should be sent to the sea-side, and while there sea-water baths, or, if they cannot be obtained, baths containing sea-salt, are very valuable. The bath should be slightly tepid, and after the bath friction, especially to the limbs and abdomen, should be employed, and continued for twenty minutes till the patient is in a thorough glow. Any complications which arise must, of course, be treated on the ordinary medical lines, and need not be considered here.

From the surgical point of view we have especially to consider the deformities which are very apt to occur in cases of rickets. Where we have to do with progressing rickets, the child should not be allowed to stand or run about, otherwise deformity of the lower limbs and pelvis will almost certainly occur. If in the country, it should be kept lying on a hard mattress, or still better, allowed to lie and play in a sunny place on a heap of sand. If the deformity of the limbs is only slight, the probability is that the child will outgrow it if standing and walking are prevented, and more especially if friction of the affected limbs is attended to and manipulations of the deformity carried out in such a way as gradually to unbend the curve.

Where, however, the curve is marked before the patient comes under the notice of the surgeon, we have to consider the question either of the application of splints or of osteotomy with the view of remedying the deformity. While the rickets is progressing and the bones are still soft, the application of apparatus is the proper treatment. Operation in such cases would lead only to disappointment; the deformity would almost certainly recur when the child began to

walk about, and in some cases the bones do not unite after the operation. Where, on the other hand, the rickets has passed off, and we have to do with dense bone, splints cannot be expected to exercise any effect, and operation must be considered.

OSTEOMALACIA.

This is a disease usually occurring in adult women after pregnancy, the chief manifestation of which is softening of the bones. In osteomalacia rarefaction of the bones takes place, with loss of calcareous salts, the bones in the first instance becoming slightly enlarged, the medullary cavity increasing in size and containing red marrow, and the shell of the bone becoming very much thinned and often perforated like a sieve. These bones are extremely liable to undergo fracture, and, apart from fracture, they bend in a most extraordinary manner. Associated with this increasing change in the bones is usually very severe pain of a neuralgic character, and the patient suffers in health and strength. The disease is an extremely grave one, and usually proves fatal in about two years from its commencement, death occurring from marasmus, cachexia, asphyxia, or some acute affection of the respiratory organs.

As regards **treatment,** in the first instance the patient should be put under the best conditions as regards hygiene, and lately improvement has been recorded from the use of tabloids of bone-marrow. As to drugs, phosphorus, phosphoric acid, and more especially phosphate of zinc, $\frac{1}{20}$ or $\frac{1}{25}$ grain, given in a pill three times a day, are advocated, but they do not exercise any particular effect. If the patient is pregnant, it is often well to produce abortion. Some report good results from oöphorectomy.

OSTEITIS DEFORMANS.

This is a rare disease which occurs after the age of forty-five and affects males more often than females. It begins insidiously or with pain and aching in the bone; it usually commences in the lower extremities, but it soon spreads over the chief bones of the skeleton. The bones become enlarged, heavy, and bent; the femur and tibia become arched forward, and walking is difficult from the weight, deformity, and muscular weakness. The spinal column becomes bent, rigid, and thickened. There is loss of height, the hands hang lower than usual, the shoulders are rounded, the head projects forward, the chin is raised, and the chest is sunk on the pelvis. On making sections of the bones they are found to be much thickened and cancellous. The change consists in absorption of the dense bone and rarefying osteitis, resulting in parts in the formation of large and irregular Haversian canals, while in other parts formative processes are going on. The cause of the trouble is not known.

As regards the **prognosis,** the disease usually steadily progresses in spite of any treatment, and it may go on for years; ultimately the patient dies from exhaustion, although in some cases death may occur from the development of malignant tumors in connection with the bone.

The **treatment** is practically *nil*. The patient is generally put on a milk diet, alkalies given, tabloids of bone-marrow or thyroid extract may be administered, and he is placed under the best hygienic conditions. Massage is employed with the view of keeping the muscles in vigor, but nothing seems to have any real power in arresting the disease.

ACROMEGALY.

This disease generally commences between the ages of fifteen and thirty-five, and consists in enlargement of the hands and forearms, the feet, the jaw, and sometimes of other bones. It is accompanied by mental slowness and very often imbecility, wasting of muscles, exaggeration or loss of reflexes, and increasing weakness. The bones are more porous than usual. The cause is unknown; the pituitary body has been found enlarged in several cases. Many giants are acromegalic. The patients usually die comparatively young, of phthisis or some infective disease; their resisting power is very slight.

The **treatment** is absolutely *nil*. Tabloids of thyroid extract or of pituitary body are usually prescribed.

LEONTIASIS OSSIUM.

This is a disease which is characterized by the occurrence of marked outgrowths on the upper jaw, and sometimes on the skull. These outgrowths consist of masses of spongy bone which may fill up the antrum, the nasal cavity, and the orbit, or press upward against the base of the skull, causing serious effects from the pressure—for example, in the case of the orbit leading to atrophy of the optic nerve, and ultimately to blindness. Very frequently the patient dies as the result of intracranial pressure. Here again the etiology of the disease is unknown, and there is practically no remedy. In some cases the bosses in the upper jaw may be chiselled away if they are found to be projecting into the orbit, or portions may be removed which are pressing on the base of the skull; but the disease recurs almost immediately.

TUMORS OF BONE.

Many tumors occur in bone, either developing primarily in the bone, or as secondary tumors in connection with growths in distant parts, or again from involvement of the bone in tumors commencing in the soft parts in the neighborhood.

The primary tumors of bone are chiefly exostoses, chondromata, and various forms of sarcomata. The secondary tumors are sarcomata and carcinomata. Hyatid cysts are also said to occur in bones. The treatment of tumors of bone depends on the nature of the tumor and the bone affected.

The **exostoses** of bones occur in two forms: the sessile exostoses, which are chiefly found on the skull, and the spongy exostoses, which occur generally about the neighborhood of the epiphyseal lines of bones. The spongy exostoses may be multiple, and may interfere very much with the movements of the joint or the muscles in the neighborhood. They are hard and knobby on the surface, and are firmly

attached to the bone in the neighborhood of the joints. They are composed of cancellous bone, and grow at the surface from a layer of cartilage which covers them. This cartilage very soon completely ossifies at the point where the exostosis is attached to the bone, and thus growth ceases at that point, whereas it continues in all directions on the surface, giving rise to the overhanging character of the tumor, so that a tumor which may be in reality very large may have only a very narrow neck of junction with the bone.

The **treatment** of these exostoses is removal wherever they are causing any trouble. If the operation is done antiseptically, it is free from danger. The operation consists in making an incision toward one side of the tumor, so as to get at the neck, exposing the point of attachment to the bone, and, after clearing it, chiselling it across close to the bone. The exostosis can then usually be shelled out of the tissue in which it is lying without any trouble. If it has involved any tendon or nerve in the overhanging processes, these must be carefully cleared. Asepsis is imperative.

The *sessile* or *ivory exostoses* are composed of dense bone usually showing only lacunæ and canaliculi, but no Haversian canals. They seldom attain any great size, and are generally found on the skull. Beyond producing a little deformity, they do not, as a rule, cause any trouble to the patient, and therefore their removal is seldom called for unless as a matter of personal appearance. The operation is not altogether free from risk. The exostoses themselves are extremely dense, and considerable force is required to chip them off, so that in exercising the necessary amount of force in the case of the skull one may produce a fissured fracture. Where the exostosis is small, a large trephine may be placed over and including the exostosis, and the whole thickness of the skull, or at any rate the outer table, removed; but, as a rule, unless under special circumstances, where they are causing pressure on nerves, or where they are growing into the orbit or pressing on the brain, they are better left alone.

Chondromata.—These are also common tumors of bones, and they most frequently occur in connection with the phalanges or metacarpal bones. They are usually multiple, and may grow either from the outside of the bone or in the interior. They are usually benign. The chondromata, on the other hand, may give rise to very remarkable deformity from the presence of multiple tumors in connection with the bones, and may interfere very seriously with the usefulness of the hand from pressure on the tendons, interference with movements of joints, etc. The tumors are generally smooth, often knobby and somewhat elastic.

Treatment.—In most cases it is advisable to remove these enchondromata in the early stage, because they usually go on growing and attain a size which ultimately interferes with the movements of the part. In removing them it is usually sufficient to cut down on the tumor, chisel away the projecting portion, and then thoroughly gouge away any deposits of cartilage which may be present in the neighborhood. If they are growing in the interior of the bone, one must chisel through the shell of the bone and scoop out the soft enchondromatous material from the interior. It is seldom necessary to amputate

a finger or to remove a metacarpal bone on account of these enchondromata. In some cases these enchondromata do not appear to be quite simple, and where there is a suspicion of any malignant character about the growth, it is better to amputate if possible; but, as a rule, these semi-malignant enchondromata are not those which occur on the hands or feet. They are usually those which occur about the pelvis and other parts, where their removal is not possible, and the probability is that they are a combination of sarcoma and chondroma.

Sarcomata of bone may be of various kinds. Perhaps the most common is the osteosarcoma or periosteal sarcoma, which begins in the periosteum of the bones and spreads along the periosteum for a very considerable distance. These tumors usually show very imperfect ossification, and the secondary tumors occurring in the lungs and elsewhere generally show the same. This is a very malignant form of sarcoma, and the chances of rescuing the patient by operation are very small. Nevertheless, one should give the patient a chance, and the best prospect is in amputation wide of the disease. In these cases of periosteal sarcoma no attempt should be made to save any portion of the affected bone; the operation must be performed through or above the neighboring joint. Unfortunately, however, metastatic deposits occur very early in these cases, affecting the glands and the lungs, and the great majority of these cases of osteosarcomata recur after removal. The bone most frequently affected is the femur. The disease gives rise to enlargement generally at the lower end of the femur, usually more or less unilateral, extending upward along the shaft of the femur.

Spindle-celled sarcomata also occur in connection with the periosteum of bones, giving rise to tumors not readily distinguishable from the osteosarcomata just referred to. In this case also amputation through the bone or joint above is the best practice.

Round-celled sarcoma also occurs in connection with bones, and it very often grows in the interior, perhaps the most common seat being the head of the humerus. Here we have to deal with a very malignant tumor. In these cases of round-celled sarcomata there is marked enlargement of the bone, and the tumor is soft in consistence where it has burst through the shell of the bone. One point of importance is that it very seldom destroys the articular cartilage and spreads into the joint. Where it spreads on to a neighboring bone, it is by bursting through the shell of the bone beyond the articular cartilage and spreading in the ligaments of the joint. This should be very carefully borne in mind, and, as a matter of fact, in amputation of the upper arm for round-celled sarcoma of the humerus, for example, the ligaments of the joint and the articular surface of the scapula should also be removed.

Myeloid sarcoma grows especially about the lower end of the femur, the lower end of the tibia, and the lower jaw. This is the least malignant of all the forms of sarcomata; in fact, it is a question whether it should be included in that group at all. Growing in the situations mentioned, it usually commences in the interior of the bone, and leads to expansion of the end of the bone, which after a time becomes more or less one-sided. Ultimately it perforates the bone and extends in the soft tissues. It forms there a fairly well-limited soft swelling on the

side of the bone, often cystic in character. On section, a myeloid sarcoma is of a chocolate color, and usually contains numerous cysts in the interior, as the result of mucous degeneration commencing in connection with the large myeloid cells.

As regards **treatment,** on account of the lesser degree of malignity, it is not necessary to treat the cases so thoroughly as in the other forms of sarcoma; in fact, in a considerable number of cases the myeloid tumor may be simply scraped away. If this is done, it must be done very thoroughly, and one must be quite sure that all the growth has been removed, otherwise, of course, it will recur. Apparently, however, it does not spread and infiltrate the tissues to any great extent, so that very little tissue need be removed beyond the actual tumor itself. Sometimes, where a myeloid sarcoma has been in existence for some time, this is not feasible, because no solid bone is left behind, and in these cases it is necessary to amputate. Amputation even then need only be done through the bone a short distance above the tumor.

Malignant tumors also occur in bones secondarily to epitheliomata, carcinomata, or sarcomata elsewhere, and they lead to the formation of tumors presenting all the malignant characters, and in the case of carcinomata usually accompanied with very intense neuralgic pain.

As regards **treatment,** no attempt need be made to remove them, as they indicate extensive infection of the system, the treatment consisting in steadying the part in cases where the tumor has so eroded the bone that it has given way, and in taking measures to relieve the pain as far as possible.

CHAPTER XX.

DISEASES OF THE JOINTS.

SYNOVITIS.

SYNOVITIS is an inflammatory condition of the serous lining of a joint.

Pathology.—The clinical term "inflammation" expresses most definitely to the average professional mind the phenomena resulting from the contusion of a joint or incited by the entrance of a foreign body. The process may be simply a histologically regenerative one without the presence of bacilli, or it may advance to a destructive condition where the micro-organisms are specific in character.

Inflammation embraces the pathological conditions which are the effect of these organisms upon histological elements contained in the blood or in the tissue-cells. An excellent definition of this process is "the phagocytic method by which an organism attempts to render inert noxious elements introduced from without or arising from within." The stages of hyperemia, congestion, stasis, exudation, emigration of wandering cells or of red cells (diapedesis), are essential elements in this phagocytic process. It is not the migrated cells that chiefly produce new tissue, but the increased functional activity of the fixed tissue-cells due to the presence of this exuded element.

Resistive power being vigorous, the circulation may be restored, resorption occur, and speedy cure follow. It is argued by some authors that this process should not be classed as an inflammation, since micro-organisms are not concerned. Should the resistive power, however, be less positive, or the traumatism more severe, micro-organisms gain access, and the infection, added to congestion and exudation, will result in emigration of leukocytes and other cells, phagocytic conflict, and the resultant débris of destructive action—pus.

Contusions, sprains, or any form of traumatism, direct or indirect, may be productive of a hyperemia followed by the ordinary phenomena of an inflammatory process, with loss of function and increased exudate of normal joint-fluid, or, in further continuance of the process, by fibrinous exudate. Should the articulation become infected by pyogenic cocci, either from without or from within, suppuration will follow, with destruction of the cartilage; or the process may advance to bone-disease, a condition which will be described under Arthritis.

Flexion is favored by distention and by muscular contraction in the attempt to place the joint at rest. In the slow or chronic variety the distention may increase very gradually and be unaccompanied by any of the ordinary symptoms enumerated. In certain joints, as in the

knee, where the area of synovial membrane is large, the amount of fluid present is sometimes great. The ramifications of the membrane beneath and above the patella and the bursa beneath the quadriceps are seriously involved in the process.

The effect of rapid exudation of serum following a severe injury of the knee is well illustrated in the accompanying cut, in which the sudden increase of fluid in the bursa above and below the patella gives

FIG. 339.—Synovial effusion simulating fractured patella.

the appearance of a fracture of the bone with separation of fragments (Fig. 339).

Rheumatism, acute fevers, infectious processes of micro-organisms, etc., are also among the causes of synovitis, and will be further considered under special headings.

Diagnosis.—The diagnosis will depend upon the history of traumatism, and the differentiation of acute symptoms from those of rheumatic, septic, or other origin.

Treatment.—The essential element of treatment is rest of the affected joint. This is accomplished by the removal of weight-bearing, by fixation of the articulation with some form of splint, the application of ice-bags or of the ice-coil, and local evaporating lotions of witch hazel, tincture of opium, or astringents. The employment of hot douching for an hour following the reception of a sprain will frequently greatly lessen not only the pain but the resultant effects. This process may be repeated with advantage once or twice during the first twenty-four hours following an injury. Absolute rest, by arresting hyperemia and subsequent inflammation, guards against resultant ankylosis. The more complete the enforcement of rest, the more certain will be the abortive effects; consequently confinement to bed or the employment of crutches and splints is of the greatest importance.

Splints of wood, felt, tin, silicate, or plaster of Paris are especially helpful by resisting muscular action and preventing even the slightest

movement of the joint. The splint cannot be applied too early, as an abortion of the process will often save weeks or months of disability or disease, and effusion often takes place within a few hours after the injury.

Serous effusion may be treated by local counterirritants, blisters, pressure with compressed sponge, or by aseptic aspiration. Aspiration, if cleanly performed, should be employed early in order to promote speedy recovery of circulation in the compressed serous membrane. Adhesive-plaster strapping will greatly assist in absorption of fluid and in giving uniform support to a joint, and is preferable to an ordinary bandage. When applied to the entire convexity of a joint it greatly limits motion.

Suppurative synovitis should be tested with an aspirator, and if streptococci are present, incision with irrigation, and drainage if necessary, should be practised.

Septic synovitis occurring in the course of an acute septic condition has its origin from toxic elements in the blood, and suppuration is the rule; consequently early incision with cleansing is essential. Caution, however, should be exercised in irrigating a joint. Simple sterile water is best, but weak solutions of bichlorid (1 : 10,000), chlorid of zinc (1 : 5000), or formaldehyd (1 : 1000) may be employed.

ARTHRITIS.

Arthritis, or acute articular osteitis, is an inflammatory condition of the joint-structures, involving both synovial membrane and the surrounding hard and soft tissues.

Etiology.—The forms of arthritis are classified chiefly according to their causes, as traumatic, rheumatic, gonorrheal, tubercular, febrile, etc., which will be considered under their special headings.

Symptoms.—Arthritis may commence as a synovitis, extension occurring from the synovial membrane to the cartilage, thence to the bone-structures; or the process may advance from the bone toward the articulation, as in tubercular osteomyelitis. The process is ordinarily less acute than in synovitis; the pain is intense, while the exudation of the tissues about the joint will vary with the causative disease. Flexion is the rule, and night-cries are common, from the impingement of the inflamed surfaces.

In simple traumatic arthritis without a septic cause, the symptoms will at first be similar to those described under Synovitis; but the steady extension to the surrounding structures soon gives evidence of a wider area of involvement, even to bony structure. Pain is usually severe; redness, heat, and swelling are more marked, and infection from staphylococci and streptococci is rapid. In the chronic forms of tubercular and rheumatoid arthritis the symptoms are slow and insidious, and their recognition is more difficult.

Acute suppurative arthritis often arises from punctured septic wounds ending in complete ankylosis. The skiagraph exhibits a non-suppurative punctured wound in childhood resulting in ankylosis so absolute that the cancellated tissue of the femur and that of the tibia appear in adult life to be absolutely continuous (Fig. 340).

Pathology.—In simple arthritis the process is primarily one of hyperemia, as described under Synovitis, the condition being accompanied early by the exudation of cell-elements into the surrounding tissues. Should this exudate degenerate, either from infection by pyogenic cocci or from external causes, suppuration will follow, with the loss of bone-substance. In septic, gonorrheal, and similar infections suppuration may take place in a few hours.

Diagnosis.—The diagnosis of the existence of arthritis is not difficult, but the discovery of the cause will include a review of the

FIG. 340.—Total obliteration of the knee-joint, with fusion of femur and tibia.

entire history and progress of the disease with all its attendant symptoms. The stealthy advance of a tubercular process in a joint where resistive power has been temporarily reduced by an injury is so frequent that its occurrence should always be suspected. Induration, doughy in character, especially when situated over the neighboring bone-areas rather than directly about the articulation, should at once arouse suspicion of tuberculosis.

Rheumatic and gouty arthritis are usually accompanied by fever and other constitutional symptoms, and several joints are liable to be infected. In rheumatoid or dry arthritis the onset is slow, creaking is often distinct, and nodosities are common.

Bursæ about the knee, when chronically inflamed, will give to the surgeon the sensation of a localized soft fluctuating tumor, and will be accompanied with lameness and tenderness. Flexion is usually absent, or not so marked as in joint-inflammation.

The **prognosis** will necessarily depend upon the severity of the process and the character of the infection.

Treatment.—The treatment will include the removal of the exciting cause, and the control of the condition as indicated under the special forms of arthritis. Rest should primarily be thoroughly enforced in bed, or later upon crutches in the open air, provided the lower limb be the one affected. Weight-and-pulley extension is often of service. Splints of wood or plaster are of absolute importance. Locally, iodin, blisters, absorbent liniments, mercury, belladonna, etc. are helpful. Internally, potassium iodid, arsenic, iron, cod-liver oil, etc. are indicated. Surgically, in all the suppurative forms, early incision, washing, and drainage are essential. Erasion and excision may become necessary, and amputation must be practised in special cases.

Acute Gouty Arthritis.—Acute gouty arthritis is a form of joint-inflammation due to perverted nutrition and the accumulation of uric acid salts in the blood, producing deposits of sodium urate, etc., especially in the smaller articulations.

Etiology.—Gout is a disease in which the income of nutrition is greater than the outgo of waste. Limited excretion and the accumulation of uric acid, producing derangement of nutrition, are recognized factors. Both defective oxidation and defective elimination are present. Active cell-proliferation probably causes the primary disturbance, while the deposits are secondary.

Heredity plays a most important part in the production of this disease. The special originating causes are excesses, especially in the use of alcoholic liquors and the heavier wines and in food-supply, although it is erroneous to assume that this disease is necessarily one of luxury. A deficient amount of food and lack of air and sunshine are also frequent causes.

The smaller articulations suffer more than the larger ones, and various manifestations of poison are found in the throat, head, eyes, and all portions of the body.

The acute variety is sudden in its onset and accompanied by the most excruciating pain, with other inflammatory symptoms in the smaller joints. Its exacerbations are most severe at night. I have seen violent attacks occurring in one night, following an excessive use of champagne, with inflammatory symptoms sufficiently severe to end in suppuration of a knee.

Treatment.—The cure of gouty arthritis consists in the elimination of the cause and the combating of the articular inflammation. The most hopeful aids are alkaline waters, diuretics, diaphoretics, and cathartics, with abundant fluids. Local anodyne applications relieve pain. Superheated hot air (see p. 697) is useful, as it assists in the absorption of the uric-acid deposit. Care must be taken, however, when this treatment is employed, that the products thus scattered shall not be retained in the system, but that they shall be flushed out either through the kidneys, or intestines, or skin. Operative interference will

be called for in cases of joint-suppuration. In such cases the treatment will be washing and drainage as in ordinary suppurative arthritis.

Acute Rheumatic Arthritis.—Rheumatic arthritis is an inflammatory condition of a joint produced by a special poison, probably chemical, but possibly a saprophytic organism acting upon the fibrous tissues.

Etiology and Symptoms.—Various organisms are claimed to be quite persistently present, a delicate diplococcus differing from that of pneumonia, the various streptococci, the staphylococci, etc., but their causative effect is not yet definitely fixed.

Achaline,[1] from researches on both dead and living bodies, claims to have discovered an abundance of rod-shaped aërobic bacilli in a state of pure culture in the normal fluids, myocardium, and diseased valves of the heart. Biologically the bacillus is peculiar in that its culture gives rise to the production of lactic and other acids. Inoculation gives characteristic lesions, and guinea-pig inoculation-serum gives rise to lesions of endocardium and pleura. Triboulet and Cayon[2] also claim to have isolated the diplococcus. A joint synovial membrane, being excessively vascular, may readily receive either microbes or toxins directly from the vessels.

Lithemia, a condition of defective eliminative metabolism, has very properly been long considered one of the chief causes of rheumatism, and it is probable that the cause is chemical rather than bacterial. Certainly an excess of uric acid exists in the blood of most rheumatics.

Diagnosis.—The chief surgical interest in this disease will lie in the effort to differentiate the acute condition of joint-inflammation from septic hygienic and other processes in the joint, from epiphysitis, acute arthritis, osteomyelitis, and tubercular disease. Hundreds of tubercular joints are lost through the mistaken diagnosis of rheumatism. In children it would be far better to adopt the rule that rheumatism of a single joint without positive symptoms never occurs. The slow onset of tubercular disease and the early rigidity of muscles are sufficiently distinctive to establish a diagnosis.

In acute infectious processes in the bone the rapid progress of the symptoms and the speedy advancement to suppuration are diagnostic. The habit of attributing all joint-pains to rheumatism is one of the most fateful of errors.

Treatment.—Medicinally, the treatment consists in the employment of salicylates, salol, oil of wintergreen, methylic salicylate, etc. Spermin has also been advocated for its metabolic action.

Surgically, local anodynes will relieve pain. The application of the *X*-rays to acute rheumatic joints has been stated to be helpful in the arrest of the process.

During the acute stage absolute rest in bed and the application of splints to limit motion and thus prevent inflammatory deposits are essential. Fibrinous exudates are best absorbed by the use of superheated dry air, which assists in the softening of the exudate and then in its being carried on by the increased local circulation. The apparatus for the application of superheated air consists of a brass cylinder (Fig. 341) 30 inches long by 16 inches in diameter, thickly lined with asbestos and magnesia, and heated below by gas, alcohol, or oil. One end of such cylinder consists of a canvas sleeve with a drawing string to grasp the inserted leg or arm. A special sleeve with four flaps per-

[1] *Annal. de l' Institut. Pasteur*, Nov., 1897; Gaillard's *Med. Jour.*, March, 1898.
[2] *Medical Standard*, April, 1898.

mits adaptation to shoulder, hip, back, or loins, thus rendering helpful service in lumbago, sprained shoulder, etc. The part to be treated is protected by a number of layers of cheese-cloth, gauze, or lint, loosely held in place. If tightly bandaged, blistering is apt to occur. The limb should be inserted at about 150° F., and although the boiling point of water is 212° F., yet the majority of patients will bear 250° F. after the first treatment without burning. The highest point that I have reached without injury has been 383° F. The perspiration of the

FIG. 341.—Cylinder for the application of superheated dry air.

part treated is absorbed by the gauze and dissipated in the intense dry heat of the cylinder, or carried off through sliding trap-doors, thus avoiding blistering. The treatment may be continued from thirty to sixty minutes, after which the part should be bathed with alcohol, or massaged with cocoanut oil to assist in absorption. Gentle passive motion is helpful.

In many cases, while the local temperature is elevated, the general temperature is not raised more than a fraction of a degree. The heart's action is increased from 5 to 10 beats, and profuse perspiration is the rule, requiring the removal of surplus clothing. Softening of the deposits following acute rheumatic arthritis is marked, and their absorption greatly promoted. In chronic rheumatism a varying degree of permanent good is secured and pain is relieved. In rheumatoid arthritis the benefit, of course, is not so great, but comfort is obtained. In the absorption of inflammatory deposits, and in the "rheumatic pains" that so commonly follow sprains, fractures, etc., the greatest benefit is secured. In lumbago, sciatica, and shoulder-sprains decided comfort is realized.

In tubercular joints the process theoretically is so dangerous that the

writer has hesitated to make the clinical experiment, lest the tubercular infecting bacilli be swept on in the circulation to involve fresh areas, or lest undue activity be developed in the local diseased area.

When partial ankylosis exists, much assistance will be rendered by massage and passive movements following the softening process secured by the use of hot air; or hot douches may be practised. Varying forms of gymnastics are also helpful.

O'Conor[1] argues that rheumatism is an acute septic arthritis analogous to the gonorrheal or pyemic variety, and that the joint-structures are incubators for the subsequent distribution of the poison through the blood vessels to the heart and to the other articulations. Reasoning from his experience of 10 cases, he advocates the immediate opening of the joint and irrigation with 1 : 5000 bichlorid and drainage.

Rheumatoid Arthritis.—Synonyms.—Arthritis deformans; Osteitis deformans; Osteo-arthritis; Dry arthritis; Arthritis sicca; Rheumatic gout; Nodosities of the joints.

Pathology.—Attempts have been make to discover the specific organism producing this disease. Bannatyne and Wohlmann claim to have successfully demonstrated the presence of a minute dumb-bell bacillus which can be stained by gentian violet and by anilin-methylene blue. Whether this condition is due to microbes or to inherent elements in the blood, hereditary or acquired, the result is one of slow, steadily progressive proliferation of cells, tending to destruction of joint-cartilage with deposition of bone-nodosities within and around the articulations. These depositions under attrition may harden and become eburnated, and progressive fixation of the joint may occur.

Recent investigations[2] in a tomb of the Fifth Dynasty revealed a skeleton at least 5500 years old showing polyarticular degenerative changes of cartilages and bones, with nodosities, eburnation, and grooves characteristic of rheumatoid arthritis.

Etiology and Symptoms.—While rheumatism and gout are frequently found in the ancestry of these sufferers, yet its existence probably exerts no greater influence than antecedent debilitating and exhaustive conditions, such as lack of sunshine, gonorrheal rheumatism, alcoholism, etc.

The monarticular form of this disease is usually found in elderly people, and, as seen by the surgeon, exists chiefly as one form of senile arthritis of hip and knee. The polyarticular variety is found in adults; occasionally in children. The onset is slow, with exacerbations of pain, limping, progressive interference with joint-motion, creaking and grating within the joint, and ultimately ankylosis. Sometimes it involves almost every joint of the body, including the spine.

A distinction should be made between osteo-arthritis and rheumatoid arthritis, the latter being distinguished by swelling of the joint during the acute and subacute stages, followed by atrophy in the region of the joint, and by atrophy of the muscles with hyperextension. In osteo-arthritis there is great proliferation of cartilage with deposit of osteophytes (Heberden's nodes); distortion is greater, and the joint remains permanently larger. In the fingers the deformity is usually hyperextension with lateral distortion and atrophy of the muscles (Figs. 342, 343). In the larger joints flexion is the rule. The character of the deposit about the shoulder and hip is well illustrated by the accompanying illustrations (Figs. 344–346).

[1] *Glasgow Med. Jour.*, Oct., 1897; *Phila. Med. Jour.*, Feb., 1898; *Annals of Surgery*, Feb., 1898, April, 1899.

[2] *Brit. Med. Jour.*, Dec. 4, 1897; *Univ. Med. Mag.*, Feb., 1898.

Diagnosis.—Diagnosis from tubercular disease will depend upon the history of the case and the density of the nodosities, in contradistinction to doughy thickening. In tuberculosis, also, muscular rigidity will occur early and be more marked. The onset in both cases is slow. In tuberculosis the condition tends to suppuration; in osteo-arthritis, to stalactitic deposits around the joints. Depositions in the muscles will lead to a diagnosis in myositis ossificans.

Prognosis.—The disease is most insidious and persistent, often running a course of from ten to twenty years.

Treatment.—Granting that the disease is of bacterial origin, the best medical eliminatives would be guaiacol carbonate, creosotal, and benzosol, the first-named drug being less objectionable to the stomach in doses varying from 5 to 15 grains, and increased as advisable. This

FIGS. 342, 343.—Effect of chronic rheumatoid arthritis on the hands (Adams).

drug is supposed to combine with the bacterial toxins, and by elimination of the guaiacol sulphate to have a beneficial action. Other helpful medication consists in the use of arsenic, Lugol's solution of iodin, cod-liver oil, potassium iodid, and digestives. Locally, massage with guaiacol and olive oil gives comfort, and hot baths are recommended, especially if thermal springs are available. The application of superheated dry air as described on page 697 is helpful in relieving pain and in absorbing deposit, the temperature being carried to from 250° F. to 400° F. according to the comfort of the patient.

Surgical treatment should vary according to the type of the disease —that is, in osteo-arthritis motion should be slight and guarded; in rheumatoid arthritis rest should be enforced during the acute stage,

but more vigorous exertion is advisable after the inflammatory process has subsided. Active and passive motions, even under anesthesia, are helpful, and the use of the articulation is to be encouraged. Sometimes, but rarely, electricity and electric radiant baths are of service.

Surgically, benefit is derived in some cases from tenotomy of the contracted tendons, especially the hamstrings. This prevents atrophy and improves locomotion. If a single joint is deformed, chiselling of the nodosities might prove of temporary service in permitting locomotion.

FIG. 344.—Shoulder-joint in a case of chronic rheumatoid arthritis (Adams).

The *X*-rays are helpful in diagnosing this disease from other joint-conditions.

Gonorrheal Arthritis.—Synonyms.—Gonorrheal rheumatism; Gonorrheal arthritis; Tripper rheumatismus; Gonocele; Urethral rheumatism; Urethral synovitis; Arthropathie blennorrhagique; Rheumatismus gonorrhoisch; Rheumatismus blennorrhoicus.

Etiology.—This disease is the result of septic infection due to the implantation of gonococci, or their ptomains, or of secondary infections in the fertile soil of the articulations. The amount of urethral inflammation bears no relation to the attack. The presence of gonococci is usually demonstrable in the infected joint both by preparations and by cultures. When non-discoverable, the examination may have been

made too late, or the free exudate, and not the tissues, may have been selected. Even after the disappearance of the gonococci the resultant pathological changes may continue.

Symptoms.—The onset is usually sudden, in the third or fourth week of an attack of gonorrhea, and is sometimes, but not always, accompanied by a disappearance of the local discharge. It may attack any joint in the body, but preferably the knee, ankle, and wrist. The progress of the disease is essentially that of a septic arthritis. Often there is rapid destruction of the joint-structures, with suppuration, or

FIG. 345.—Acetabulum of an adult who had long suffered from chronic rheumatoid arthritis (Adams).

FIG. 346.—Posterior view of head, neck, and superior extremity in a case of chronic rheumatoid arthritis of the hip (Adams).

there may be ankylosis without suppuration, especially at the wrist and carpus. Swelling is marked; pain and constitutional symptoms are severe at night. Gonorrheal bursitis may occur beneath the insertion of the tendo Achillis (achillodynia) or above the patella.

Diagnosis.—The recent existence of urethral disease will, unless concealed, lead the surgeon in the proper direction.

Treatment.—Treatment should be promptly instituted, especially if there has been a subsidence of the urethral discharge, and if acute symptoms are present. Absolute rest of the joint or joints is essential, and hot irrigations of the urethra with sterile water or a weak solution of potassium permanganate may be practised. There should be absolute fixation of the joint with gypsum or other splint until acute inflammatory symptoms have passed, after which the joint should be gently moved to prevent the ever-present tendency to ankylosis. As soon as evidences of suppuration appear, incision and thorough

cleansing with bichlorid (1 : 5000) or formaldehyd (1 : 2000) and complete drainage of the joint are requisite. Subsequent ankylosis should be treated by forcible straightening, tenotomies, etc.

Tubercular Osteitic Arthritis.—Synonyms.—Joint-tuberculosis; White swelling; Gelatinous or Pulpy or Fungous degeneration; Strumous arthritis.

Pathology.—Tuberculosis in the region of the joints, whether of the trunk or extremities, is essentially a bone-tuberculosis (osteitis), although it occasionally originates in the synovial membrane (arthritis). It is a disease of infection, caused by the presence of the tubercle bacillus, and accompanied by the formation of circumscribed nodules, called tubercles, in the tissues adjacent to and within the diseased joints.

A tubercular nodule in bone consists of a collection of round and variously formed cells, the most constant of which is the epithelioid. These cells (platycytes) resemble endothelium, and are of finely granulated protoplasm with small ovoid nuclei. In addition to these epithelioid bodies, peripherally polynucleated giant-cells (macrophagocytes) are very constantly found, grouped in masses and fewer in number. Tubercle bacilli, rod-shaped, may be found within or adherent to any of these cells. The epithelioid cells are probably derived from the blood-vessels or by proliferation of the previously existing cells, as a result of the activity induced by the presence of the bacilli.

The active central cells are probably derived from leukocytes; the giant-cells may be fused epithelial cells, or their origin may be from degenerated cells by proliferation without separation of protoplasm, even although the nuclei divide. Small round cells similar to those found in young granulation-tissue also occupy a considerable space in the tuberculous nodule, and blood-plaques are sometimes seen.

When a tuberculous nodule retrogrades, polynuclear leukocytes make their appearance; fatty degeneration takes place, and caseation with liquefaction follows. If favorable fibroid encapsulation takes place from an erected wall of defence, calcification will occur, and the débris of bacilli and their ptomaïns may remain quiescent for a long period of time, or the entire mass may work its way toward the surface and be discharged in the form of a cold abscess. The irritation caused by the tubercle bacilli often excites inflammatory processes, and if staphylococcus infection is added, suppuration ensues, and the tubercular nodule may finally be eliminated by this method; but suppuration is not an essential part of a tubercular process. The changes in a tubercular nodule closely resemble those seen in ordinary inflammation.

The action of bacilli is essentially destructive, but their presence immediately arouses a procedure which has been already described as "the method by which organisms attempt to render inert noxious elements introduced from without or arising from within." Following hyperemia, congestion, stasis, and emigration of red and white cells, phagocytosis becomes active, and a process beneficial to the tissues is aroused, since rapid tissue-changes are inimical to the growth and development of bacilli.

Bacillary infection may occur from without, leaving no trace of local infection at the atrium, or from within through the blood-vessels. Lodgement of these micro-organisms having occurred in or near a joint in a healthy individual, the invaders are overpowered by the defenders, and no injury results. Under the influence of slight injury, however, or from inherent cell-weakness, this defensive power having been temporarily or permanently lost, a foothold is gained and the point of attack fortified. A tubercular nodule is the result. Garrisoned on this vantage ground, the bacilli or their spores lurk prepared to renew the assault at any near or remote moment when the defenders are off duty or are engaged in repelling other invaders, or when their resistive powers are lessened by traumatism, by fever, or by other cause.

The important part that heredity plays in this process is simply that the cells are less resistive and less capable of withstanding assault; such impaired vitalization having been imparted through spermatozoid or ovum in the same manner as are other characteristics.

The term heredity implies a condition of tissue, not a disease. Thus it is evident that the infection of tuberculosis is influenced by ancestral legacies, by personal habits of life, and by temporary and permanent local conditions. When the distinctive symptoms of joint-tuberculosis are present, the non-existence of tubercle in the family history is of little moment, save for prognosis, since any individual may develop local tuberculosis.

The abolition of the old terms "white swelling," scrofulous joint, etc., which served their purpose for clinical description, has been due to realization of the unity of the tuberculous process. The use of the term scrofulous still serves clinically, however, to denote a non-resistant condition of the tissues, subjecting the individual to a degenerative process which tends, not to organization, but to disintegration of the structures. Traumatism, heredity, scrofulosis, environment, and local conditions are all concerned in the production of local bone-tuberculosis. Traumatism certainly plays a most important part in this pathological process by setting up an inflammatory condition which destroys the power of resistance of the tissue-cells against the enemy—the tubercle bacillus. In severe injuries cell-resistance is more thoroughly aroused than in slight joint-contusions, and infection by the bacillus is thereby more readily repelled.

Tuberculosis of the synovial membrane, if primary, may cause a diffused thickening of the membrane or the direct formation of tubercular nodules. Pulpy degeneration follows, and as the supply of blood diminishes, the cartilage loses its vitality, macerates, and becomes infiltrated with tubercular granulations. Gelatinous infiltration occurs, from perforation of the synovial membrane and infection of the surrounding tissues by the escape of tubercle cells.

Tubercular deposits in the extremities of bones usually occur primarily in or near an epiphyseal line. When the tubercular process advances to the articular surface, the cartilage may be loosened almost *en masse*, or it may be eroded, while the underlying layer of bone-tissue becomes carious.

The deposit of tubercle not infrequently causes a rarefying osteitis in the immediate neighborhood of a joint, although the presence of bacilli may not be demonstrable. The Haversian canals are enlarged coincidently with absorption of the trabeculæ and the development of granulation-tissue. Caries of the bone of the fungous variety may follow, with an excessive production of granulation-tissue. A considerable portion of the bone and joint may be destroyed—caries necrotica; or a wedge-shaped portion of the bone may become necrosed from a tubercular infarct. Even when an infarct does not exist, the deposit of tubercular material so retards circulation that articular bone-death may result from loss of nutrition. In some cases a sequestrum results, but more frequently the bone becomes slowly carious, or an abscess forms. The precise form of resultant death will depend upon the rapidity or violence of the process, or upon the existence of microbic osteomyelitis; but the latter condition is more common in the shaft of the bone than at the extremities.

FIG. 347.—Attachment of the ligamentum teres to the head of the femur; × 50.

Although the initiatory process is usually in the bone, yet the violence of the onset may sometimes appear primarily in the joint-structures, as noted in the accompanying microscopical sections taken from the insertion of the round ligament into the acetabulum (Figs. 347, 348). In this case, which was under my care, and in which the patient died of acute tubercular meningitis, the epiphysis contained no caseating nodules, but characteristic foci were found in the round ligament. The changes demonstrated were those chiefly of increased cell-activity, and not of distinct tuberculosis.

Symptoms and Etiology.—Tubercular joint-disease may occur at any age, even as early as two months. Lack of food and sunshine, bad air, and intemperance of parents are the most common factors. In children a large proportion of diseases of the joints are tubercular in character, while in adults the non-tubercular conditions preponderate.

In cases of decided injury the hyperemia, swelling, and pain in the region of the joint may be acute; but these are rather true of synovitic

cases than of tubercular osteitic arthritis. Often the pain is not located at the joint, but is manifested at some distant point. Reflex pains may be present in the knee, hip, abdomen, arm, or chest. The contour is altered, and the carriage of the body in standing, stooping, walking, etc. is changed.

In non-acute cases the period between the reception of the injury and the development of symptoms may be delayed for many months. First, a slight uneasiness or restlessness of the limb may manifest itself at night—a discomfort rather than a pain. In hip-infection this distress

FIG. 348.—Attachment of the synovial membrane to the periphery of the articular cartilage of the head of the femur; × 30.

may be referred first to the region of the adductors, then down near the inner condyle. At first the child limps only at times, afterward more persistently.

If the spine is the seat of infection, movement of the vertebræ will be avoided by carrying the body rigidly and by cautious stooping, while colicky pains will disturb the patient at night. The first stage is a variable one, with retardation or with rapid advancement under slight injuries. Such a patient stripped and examined will show, first of all, rigidity of the part involved—muscular protection. This rigidity is persistent from the earliest onset, and is the most characteristic symptom. Tenderness, swelling, and deformity are variable: the diagnosis should be made before these appear, if treatment is to be of decided avail.

Richardson has advocated the systematic auscultation of joints with single or double stethoscope. In healthy articulations no sound will be elicited, but in disease one may obtain simply dry frictions, dry grating, moist crepitant, and coarse crepitant sounds.

In the second stage, that of joint-effusion, marked limping comes on as the patient endeavors to shorten the time of impact of the sore joint-surfaces. Soon "starting pains" or "night-cries," caused by the alternate relaxation and contraction of the guarding muscles as they bring into contact the two inflamed joint-surfaces, will seriously disturb the sleep of the patient. Deformity, usually in the direction of flexion, becomes more marked as the muscles increase their efforts at protec-

tion, and reflex pains in chest, abdomen, or limbs are indicated, often at a considerable distance from the part involved. In caries of the spine local tenderness is the exception; at the other joints it is usually, but not invariably, present. Alteration of contour speedily follows, the swelling being palpable in the region of the joint, and doughy induration rapidly increases. Atrophy of the muscles also alters the normal outlines of the various regions involved. The whole aspect is so characteristic that a diagnosis of "rheumatism" can be explained only by ignorance or by carelessness in examination.

The later or third stage is one of rupture of the joint-capsule, with infection and destruction of tissues, usually suppurative. Spine, ankle, and knee distortions will not greatly alter their position at this stage; but at the hip, abduction is changed to adduction, and lengthening to shortening, both apparent and real, as bone-destruction progresses. Great thickening in the region of the joint is present, with subsequent softening and formation of abscesses or ankylosis.

Diagnosis.—Simple synovitis and acute rheumatic arthritis are sudden in their onset, with speedy rise in pulse and temperature; the latter disease may attack several joints. The history in both cases will be quite different from the sequence of symptoms seen in tubercular arthritic osteitis—slow onset, rigidity of the surrounding muscles, flexion of the joint, and atrophy.

In children, when a single joint is affected, the inference should be always in favor of tubercular disease. Mono-articular rheumatism in children without other positive symptoms should be absolutely discarded from the surgeon's mind. Hundreds of children are yearly permitted by the fateful myth of "rheumatism" to pass beyond the point where abortive treatment is possible; loss of joint-function, loss of limb, and even of life, are the result of such errors.

The onset of infantile paralysis is sometimes puzzling, as the child may cry when handled. The gait when the patient is examined naked will show a limp that is not one of inflammation but one of debility. There will be increased motion and laxity of the joint, not rigidity, and no thickening.

Inherited syphilis, it should be remembered, may [illegible] itself in joint-lesions, especially in the spine; but the tuberculous reflex spasm, rigidity of muscles, night-cries, and atrophy of muscles are certainly distinctive enough, when present, to make diagnosis assured. [illegible] [illegible], and the beginning of [illegible] are at times difficult of differentiation.

Treatment of Joint-Tuberculosis.—[illegible] better than [illegible] better than [illegible] the [illegible] and cure of joint-tuberculosis. [illegible] suffering [illegible] [illegible] [illegible] which [illegible] [illegible] [illegible] [illegible] [illegible] With [illegible] Digestives, tonics [illegible] essential conditions

are lacking. A tubercular-joint patient should actually live in the open air, and by the employment of the bed-frame this can be accomplished even where strict confinement to bed is required. The sea air, especially where it is dry, as on the New Jersey coast, has a most beneficial effect upon children with joint-trouble, although it frequently has the contrary influence upon phthisis pulmonalis. An out-door life in the country is beneficial, and even in a crowded city its results, though not so obvious, are still markedly helpful.

The beneficial effect of absolute fixation of tubercular joints is thoroughly proved. It is the superadded inflammatory condition, and not tubercular disease, that is likely to produce ankylosis. Rest is the only measure that can abort a threatened infection. Traction assists in securing rest by resisting muscular contraction, modifying joint-pressure, and relieving pain and deformity.

Counterirritation, so much relied upon, is practically useless, save as combined with rest. The benefit obtained by the use of the actual cautery in former days was doubtless largely due to the fact that it put the patient in bed for many weeks and prevented the use of the inflamed joint.

During the acute painful stage, extension by weight and pulley can be maintained in the horizontal position while the patient enjoys all the advantages of out-door life by the use of a simple tray or bed-frame or stretcher, consisting of a framework of gas-pipe or wood covered with canvas in one, two, or three sections. This can be laid upon a bed at night, while during the day the patient can be carried upon it in the horizontal position and enjoy the advantages of fresh air. Such frame can be carried in arms without the patient being disturbed from the dorsal decubitus; or it can be placed upon the platform of a long baby-coach, or rested upon chairs ,or trestles upon a porch or under shade trees, and at night placed upon a bed.

Requisite extension can be temporarily secured by elastic traction to an upright at the foot of the frame, or at the head in spinal disease. A good rule in hip-disease is to keep the patient in the horizontal position for three months after the cessation of all pain. Extension may also be made by one of the forms of traction-apparatus.

Fixation will be secured by the employment of splints of wood, felt, paper, tin, leather, plaster of Paris, or silicate. The joint should be kept at absolute rest. The diagnosis having been firmly established in the beginning, no motion should be permitted for months. When the acute stage has passed, the patient may be fitted with a proper fixation or traction splint, and treated on the ambulatory plan with crutches, high shoe, etc., as required. Gypsum bandages form the most common dressings.

Trephining of Bone.—Incision into or trephining of bone is often of service, if the precise focus can be reached. It is of special advantage where the disease has commenced in the condyle of the femur, or in the great trochanter, or in the humeral or tibial epiphyses.

Ignipuncture.—The perforation of a tubercular bone-focus with the Paquelin cautery often has a most beneficial effect.

Injections of Antibacillary Substances.—Injections of iodoform, chlorid of zinc, alcohol, or formaldehyd into a joint or into the tissues

surrounding a tubercular focus have been practised, and sometimes lauded. The writer's experience with this treatment, however, has been unfortunate, as even under the most absolute cleanliness, suppuration in many cases has been rather hastened than retarded. Boiled olive oil or glycerin with 10 per cent. sterilized iodoform added may be injected hypodermically either into the joint or into the surrounding tissues. In the latter case 10 or 15 minims of the mixture should be employed at each point of injection, and at least one dram should be used altogether; in a joint an ounce of the mixture may be employed. Pain from such injections may be mitigated by the local use of a spray of ethyl chlorid or by Schleich's tissue-pressure anesthesia. The sclerogenic treatment, or the circumferential injection at numerous points of a 10 per cent. solution of chlorid of zinc, has a decided restrictive effect. Wood-alcohol or formaldehyd is also useful by its constricting effect upon the capillaries.

Injections of Antituberculin Serum.—The injection of antiphthisin (a sozalbumin containing the germicidal elements of tuberculin), tuberculin R., repeated injections of serum and serum-products, compounds of pilocarpin, creosote, etc., have not been sufficiently tested to give definite results, but they are helpful.

Chronic Congestive Method.—The artificial chronic congestive method advanced by Bier for the destruction of the tubercle bacilli has not been received with much favor. The method consists in surcharging the joint-structures with blood by a constricting elastic bandage, the congestion being carried to a point of even blistering, etc., and followed by active and passive movements of the articulation both during the time of constriction and afterward.[1]

Aspiration.—Aspiration of a joint or of a cold abscess that contains the liquefaction of caseation will often result in the absorption and caseation of the tuberculous mass and in ultimate cure without suppuration. The process may be repeated until positive evidence of pus is found. Sterile iodoform oil (20 to 50 c.c.) or tincture of iodin may be injected through the cannula of the aspirator. If the contents of such an abscess are found to be sterile, there need be no haste in opening it.

Arthrotomy (Incision, Irrigation, and Drainage).—The laying open and washing of a joint with boiled sterilized water or sterilized bichlorid (1 : 10,000) or formaldehyd (1 : 2000) is often of great service when suppuration has commenced, and is demanded when infection is present. Drainage by rubber tubes or gauze packing is often required, the joint being filled with iodoform oil. It is almost unnecessary to say that all operations should be conducted with the utmost attention to cleanliness.

Excision of Sac.—All surgeons now realize that the sac of a tuberculous abscess is not a pyogenic but a pyophylactic membrane—a wall of defence and of limitation. When it can be completely excised with knife or scissors, such plan is most desirable; but in many cases of spinal and hip caries complete extirpation is impossible. Under such circumstances, after excision of all attainable sections the remaining sac should be approximately removed with a hollow flushing curet, infec-

[1] *Med. Press and Circular*, May 20, 1894; *Centralb. für Chirurg.*, Leipsic, 1892, No. 82; *Berliner Klinik.*, Nov., 1895; *Brit. Med. Jour.*, Dec. 21, 1895.

tion from the disturbed remaining areas being prevented by mopping with tincture of iodin, saturated solution of chlorid of zinc, or pure carbolic acid. When the sac cannot be thoroughly dealt with, the safer plan after incision and irrigation is to avoid all disturbance of the membrane even by pressure, lest fissure of the wall permit a route for entrance, and infection and meningitis result. In such cases the cavity should be injected with tincture of iodin, then filled with sterile iodoform oil (10 per cent.), and the wound closed. When pyogenic cocci are present, drainage will be required.

Erasion.—Erasion, improperly called arthrectomy, is an operation frequently employed in the later or suppurative stage of joint-disease.

FIG. 349.—Skiagraph of carious knee-joint with erosion; adult.

It includes the scraping away by gouge, knife, or scissors of all diseased hard and soft tissues, leaving behind every possible healthy portion. Thorough exposure of the articulation is necessary, and the operation is most helpful in those cases of arthritis where complete removal of the diseased area can be accomplished. In the hip, while often serviceable, it is not certain in its effects. In the spine total removal is impossible, and one must content himself with thorough drainage. Ankylosis after this operation is common, but not universal. Erasion is most useful at the wrist, ankle, elbow, and knee. In the tarsus and carpus in children the entire series of bones may be taken away, and yet a useful hand and foot may be secured, sometimes much better than

an artificial member. An important consideration in the treatment of children is the saving of the epiphyseal lines, thus ensuring growth of the limb, even though repeated operations are necessary.

Chronic sinuses leading to dead bone should be treated by erasion of the diseased osseous structures, excision of sinus walls, and cauterization with chlorid of zinc or tincture of iodin.

Excision.—The formal or typical excision of the articular surfaces of diseased bone often destroys the epiphyseal lines and checks future growth. When the tubercular destruction, however, is large in extent, this operation becomes a necessity, even in children, and is a most valuable agent in saving life and limb. It is also indicated in positive joint-destruction in adults when constitutional symptoms are not so severe as to demand amputation. The determination as to erasion or excision, or of interference with ankylosed tubercular joints where the process has subsided, may often be effectually decided by the employment of the *X*-rays, as the extent of the destructive process can be very accurately delineated (Fig. 349).

Amputation.—Sacrifice of a limb is a procedure that is not infrequently demanded in advanced joint-disease in adults, but should be avoided in children, except in pronounced and absolute destruction. Erasion, even if several times repeated, and excision, with constitutional treatment, are preferable in the young.

Neuropathic Arthritis, Spinal Arthropathy, or **Charcot's Disease of the Joints.**—In 1831, long before Charcot's observations, J. K. Mitchell, of Philadelphia, advanced the idea of an arthropathy associated with a neuropathy.

Spinal arthropathy is the name given to peculiar degenerations of the joint-structures occurring in the course of spinal-cord lesions, especially locomotor ataxia, tabes, syringomyelia, etc.

Etiology.—The essential cause is a degeneration of the spinal cord, steadily advancing in the central axis, with secondary nutritive changes in the articulations, which, under certain circumstances, lead to destruction first of the synovial membrane and fringes, then of the cartilage, and finally of the bone. These changes are slow in character, and are usually, but not always, accompanied by pain and doughy swelling, with distortion probably due to the altered nerve-supply. The process, both pathologically and clinically, differs markedly from tubercular disease. Suppuration only rarely occurs.

When associated with hemiplegia, the synovitis is usually of the exudative or vegetative type, and is found especially in the upper extremities. If associated with tabes the result of trophic changes or nerve-trunk disease, serous exudate is common, and the degenerative changes may be so great as to destroy the ligaments and permit the most extraordinary dislocations; or they may result in destruction and absorption of the entire extremity of a bone.[1]

Treatment has but little effect in staying the course of the disease. In contractions, downward traction by weight and pulley and fixation

[1] In a shoulder-arthropathy associated with syringomyelia, Spiller examined microscopically both cord and spinal ganglia with definite results (*Am. Jour. Med. Sci.*, Dec., 1896). The articulation was dislocated, eroded, and surrounded by deposits, and the entire head of the humerus had disappeared. Some 60 cases associated with syringomyelia have been recorded, most of them having occurred in the upper extremity.

are beneficial. Operative measures are of use only in relieving a false position; otherwise they are unnecessary.

NEUROMIMESIS, OR HYSTERICAL JOINT.

Nervous mimicry of joint-disease is often difficult of diagnosis, especially in a patient who, from long residence in a hospital or from self-concentration, has acquainted himself or herself with the symptoms to be anticipated from an injury of an articulation. The conditions, which at first after traumatism were undoubtedly real and positive, are finally exaggerated by the neurotic, and are mentally dwelt upon until absolute disability is developed. Following an injury, the first movements, after enforced rest, are necessarily painful, and the patient seeks to protect the joint; therefore, if a surgeon fails to differentiate between still existing conditions and the pains produced by the stiffness from slight adhesions, his error may result in a permanent condition of disability.

In all inflammatory cases there is a primary time for rest and there is a secondary time for action. After the subsidence of a simple inflammation, massage and use of the limb are of the utmost importance in producing a cure, while in tubercular infection the use of the limb must be prohibited for a long period of time. Hence the surgeon must be most judicious and skilful in his diagnosis.

Diagnosis is often obscured by actual inflammatory thickening which usually surrounds a joint to a greater or less degree after an injury. In such cases the character of the patient and the general and local symptoms must be closely studied.

When, in the absence of swelling or induration, there is excessive pain upon movement, and especially when there is marked hyperesthesia of the skin, even under the gentlest touch, a neurotic element may be strongly suspected. While actual lameness and all subjective symptoms may be present, yet they will be found altogether out of proportion to the actual palpable conditions. By engaging the patient's attention during the joint-examination and by close observation of each symptom a diagnosis may be made, although probably not at a single sitting.

In cases of doubt anesthesia may assist. In tubercular joint-lesion muscular rigidity will disappear late in the process of anesthesia, and will be renewed as soon as the individual returns from the stage of complete unconsciousness; while in a hysterical joint this muscular protection will not reappear until the individual is thoroughly conversant of his acts.

The absence of effusion and the atrophy of muscles are also important elements in diagnosis. Spinal tenderness, nerve-pains, and a general line of neuroses may assist in the recognition of the true condition.

In the **treatment** of neuromimesis it should never be forgotten that the tenderness, though aggravated, is real. The confidence and co-operation of the patient must, therefore, be secured. This must be followed by attention to the general health. Massage should be used, and mechanical, passive, and active movements should be employed.

Superheated dry air and progressive voluntary use of the joint should follow. Such a course, if carefully pursued, will result in restoring function to a joint which might otherwise become permanently disabled. Local blisters and the actual cautery are often useful, together with blistering of the lumbar spine.

LOOSE BODIES IN THE JOINTS; DISLOCATION OF CARTILAGE.

Loose or movable bodies in the joints, or floating cartilages, may be entirely free or may be partially restrained by pedicles.

Ecchondromata are formed from true cartilage of bone, or the sepa-

FIG. 350.—Dislocation of the semilunar cartilage.

rated nodosities of osteo-arthritis, or the violently detached portions of cartilage, or from overgrowths of synovial-membrane cartilage-cells. Ecchondromata are formed from the villous outgrowths of the synovial membrane which have been gradually torn free, or from degenerated fibrinous tuberculous fringes.

Symptoms.—The distinct symptom is a sudden locking of the

joint, usually the knee, while it is in a flexed position, the patient being seized with an intense pain.

The condition with which this state is most likely to be confounded is displacement of the semilunar cartilages or "internal derangement of a joint" (Fig. 350), a tearing loose of the semilunar cartilages from rupture of the coronary ligaments. This may be the effect of injury from sudden hyperextension, or from flexion or rotation, and is accompanied by severe pain and locking of the articulation.

Treatment.—Reduction of a joint locked from loose bodies is usually readily accomplished by extension followed by forcible flexion and rotation. The ancient plan of strong flexion against the edge of a table upon which the patient sits is a good one. Anesthesia may be required. Mechanical retention of the bodies by apparatus is seldom successful. When locking is frequent and locomotion troublesome, aseptic removal of the loose bodies is the only hope of cure. If an anesthetic is given, the precaution of fixation of the nodule with a tenaculum should be adopted.

Dislocation of the semilunar cartilages may be reduced in a similar manner. When the cartilages persistently slip from their positions, an apparatus which will prevent rotation of the leg upon the thigh, check the joint-action before full extension is reached, and permit only flexion of the knee will be most helpful. Should this fail, the cartilages themselves should be excised, or moored to the periosteum by silver sutures.

CHAPTER XXI.

DISEASES OF SPECIAL JOINTS (ORTHOPEDIC SURGERY).

DISEASES OF THE HIP-JOINT.

DISEASES of the hip-joint are due to changes in the capsule or the bones, impairing the use of the part. These diseases are mostly inflammatory, either chronic or acute; by far the most frequent is that called tubercular, due to the parasitic action of the tubercle bacillus, and met with on a large scale in the urban communities of temperate climates. Typical examples of this disease have been familiar for centuries, and have been termed morbus coxæ, coxitis, or hip-disease (Fig. 351).

FIG. 351.—Right hip-disease, chronic, in a boy of nine; marked flexion and adduction.

Inflammation of the hip-joint may attend other infective states, or general disorders of the system, such as pyemia, osteomyelitis, gonorrhea, scarlatina, rheumatism, rheumatoid arthritis, gout, and syphilis. Occasionally the joint is affected by the "simple inflammation" of an

uncomplicated injury, such as sprain or dislocation. The existence of these various diseases has often been certified by scientific proofs, which are sometimes applicable in clinical practice; but in many instances the definition of the actual variety of disease is chiefly a matter of inference and more or less probability. In clinical practice, many cases now inferred to be tubercular are capable of recovery, and often of complete resolution, under suitable mechanical treatment and rest; and exact proof of their nature must often be wanting, though a belief in the character of the disease is, with our present knowledge, irresistible.

Cause.—It cannot always be definitely ascertained whether tubercular hip-disease is the result of injury or has apparently arisen "spontaneously;" but there is every reason to believe that the disease arises in direct consequence of injury, although it may often occur apparently without any such contributory cause. Tubercular joint-disease, especially in children, often occurs in individuals seemingly robust and well.

The tissues affected in joint-diseases are the capsule and the bones, and inflammation may take the form of "capsular arthritis," of "osteo-arthritis," or of both. If fluid is effused within the capsule, there is said to be "synovitis," or inflammation of the synovial lining of the capsule. In some cases the synovitis may attend osteo-arthritis. In a well-defined exposed joint, like the knee, these distinctions are easily made out at the bed-side; but it is different with the hip, situated deeply among the muscles. The evidences of operation and of post-mortem examination make it certain that in hip-disease the inflammation may attack the capsule, or, usually primarily, the bones inside the capsule; but we have no certain means of deciding at the commencement, and had better therefore not attempt always to predict in which tissue the disease arises, seeing that some cases recover without defect and without trace. Whether the disease begins in the bones or in the capsule, there may be effusion of fluid, which can be detected, when in sufficient quantity, on one side or other of the joint. Such evidence of fluid apparently hardly ever produces much distention and bulging of the capsule, so that the term "synovitis" is seldom if ever applicable, in the opinion of the writer, to any of the conditions found in this particular joint. The thickening of and about the joint is due mainly to infiltration of the various tissues.

Symptoms.—The symptoms of hip-disease can best be understood by studying those of the most numerous class, the tubercular, and may be comprised under three heads—pain and tenderness, lameness, and deformity. In a typical case there are pain and tenderness in the joint, which is stiffened in the flexed position, and there is a limp or roll in the gait.

The symptoms in such a case are sometimes so definite, and so obviously point to the region affected, that their proper cause is easily recognized by a medical attendant who may have little or no previous experience to guide him. In fact, the parents or friends of the patient, or the patient alone, may not infrequently be enabled, in the light of common sense or of local perception, to form a good idea of what is the matter. But, easy though it be, in typical cases, to recognize the affection when several symptoms point to it, there is uncertainty when some, or even most, of the usual symptoms are absent, unless the observer has a varied experience of his own, or has rules laid down by the experience of others. The pain, for instance, may be insignificant, and even absent altogether; while tenderness on pressure or movement may be unnoticeable. There is then to be considered the limping or rolling gait, which is very conspicuous when due to pain or tenderness, but which is often due merely to stiffness and a fixed attitude, mostly flexion, when neither pain nor tenderness exists. In the case of infants in arms the gait cannot be tested. There then remain the adoption of certain attitudes and the stiffness of the joint, which have now to be considered.

In examining a typical case of hip-disease, with pain, tenderness, and limping, if the patient is stripped and laid on the floor, on a table, or other suitable flat surface, there is always found to be a stiffened and usually a more or less flexed attitude of the limb on the affected side. There is a want of symmetry between the lower limbs in some positions. If the legs and thighs be placed parallel in line with the body,

there is found to be bending of the trunk by increased arching of the lumbar spine, which thus cannot be brought into contact with the surface on which the patient is lying. If, however, the knees and hips be flexed equally on both sides, the lumbar spine can be flattened and the trunk thus straightened; and if flexion be the only deformity, its amount is readily ascertained and a symmetrical attitude found for the limbs and trunk. Flexion, however, is not always the sole position in which the joint is stiffened, for there may, in addition, be abduction or adduction, or there may be rotation out (Fig. 352) or rotation in. Symmetry of the trunk is secured by straightening the spine and placing the anterior iliac spines on a level, by adjusting the pelvis until the line through the sternum, umbilicus, and pubic symphysis is straight; symmetry of the limbs is secured by flexing both knees and hips as much as is required to obliterate the abnormal lumbar curve, and in the event of adduction by crossing the legs, in that of abduction by setting them apart. The attitude in which the loin and thigh are fixed on the diseased side is thus imparted to the unfixed and supple corresponding parts on the sound side. All this may appear somewhat complicated in words, but it can be understood in a few moments at a glance, with slight manipulations. An exact demonstration of the flexion, abduction, adduction, or rotation is easily made by adopting a device of the late Hugh Owen Thomas. This consists in flexing the sound hip and knee to the fullest extent, as the patient, stripped, lies on his back on a flat surface, holding the limb in that attitude against the chest while putting the diseased limb as straight as it will go. The precise amount of flexion or other deformity is then displayed in the affected hip-joint (Fig. 353). Abduction or adduction may or may not be present, and the same applies to the rotation out or in. But in every case of hip-disease *previously untreated by rigid apparatus or by effective rest in the lying posture*, a certain amount of stiffness in the flexed position is present.

FIG. 352.—Left hip-disease in a man of fifty-seven; flexion, adduction, and rotation outward.

Why should flexion or other fixed attitude be found in hip-disease? In a healthy state of the parts, all the positions and attitudes of the joint can in turn be assumed at will; but with inflammation come swelling, impairment of nutrition and function, and reflex spasm, with stiffening of the capsule and other tissues that should be pliable. All muscular movement is also more or less hindered by the stiffness, especially extension, which depends upon muscular movement alone. Flexion, though also hindered by stiffness and muscular weakness, is nevertheless favored on every attempt at sitting, when the weight of the body alone tends to fold the thigh on the trunk. The flexion tends to be confirmed, since the joint never becomes perfectly straightened in the intervals. Not only are the muscles, in the stiffened state of the inflamed parts, less effective for the usual movements of the joint, but even in

FIG. 353.—Acute left hip-disease, before treatment, in a boy of seven. Degree of flexion displayed by H. O. Thomas's test.

early cases, where the capsule is still unaffected, there may be flexion from muscular spasm. Instead of resting between their efforts, as they would in a healthy state of the parts, all the muscles around the inflamed hip-joint are, through the influence of the nervous system, brought more or less into a state of constant contraction. This action is mainly involuntary, but there may be a supplementary effort of the same kind consciously effected at the instance of the patient's own reason and experience. This rigid "watchfulness" of the muscles more or less attains, in certain cases, the effect of partially warding off pain by an attempt to keep the joint still during the waking state of the patient. When the patient, however, drops off to sleep, the muscles relax and the limb moves, causing in the joint a momentary pain under which the muscles instantly contract again, producing the well-known "starting pains." This symptom was considered, and is still by some accepted, as evidence of ulceration in the cartilages. It is not easy to say how either the truth or the error of such a supposition is to be proved; but the explanation given above seems to the writer more in accordance with reason and probability.

Flexion in hip-disease varies in degree from a flexion which brings the thigh nearly in contact with the trunk (in occasional old neglected cases) down to a point where careful tests are needful to demonstrate

the vicious position. Usually the flexion is accompanied by adduction or abduction. Abduction occurs sometimes, especially in early cases, but is less common. Later the combination of adduction with flexion is the familiar picture. No less important than the presence of deformity is the limitation of motion by muscular spasm which may occur where there is no deformity. In very early cases the only sign present may be a certain limitation of the range of motion as compared with that of the sound hip. There may be limitation of all movements, or of some only; for instance, there may be a loss of hyperextension only, or of external rotation and abduction. Any difference in the range of motion in the two hips requires explanation. If there is no other process found, it is safer to assume that there is joint-trouble (probably tubercular), to warn the parents of the patient as to the possibility of serious trouble, and to treat the case for the time being, until a definite diagnosis is possible, as one of probable hip-disease.

It is to be noted that flexion-deformity may be a result of structural changes, and hence may not yield to treatment. The same is true, to some extent, of the limitation of motion; but in general the limitation corresponds pretty closely to the acuteness of the disease (whether in early or late stage), and is therefore a better index of effectiveness of treatment than is the decrease in permanent flexion.

Since flexion is in certain cases the only symptom upon which reliance can be placed in the diagnosis of hip-disease, it becomes important to detect it with certainty. Flexion is found also in caries of the lumbar spine, with abscess in the iliac fossa. In hip-disease the spine arches readily when the limb is pressed straight while the patient lies on his back; in spinal disease, however, the knee cannot be pressed down, but remains tilted up, owing to stiffness in the flexor muscles of the hip-joint and rigidity of the spine. Such cases may be mistaken for each other, especially when attended with abscess in the groin and iliac fossa.

Another well-known symptom, "flattening of the buttock," is the result of muscular wasting; and the wasting of other muscles leads to a general atrophy of the limbs. In certain muscles this is the specific atrophy of joint-disease; there is also, however, the atrophy of disuse, affecting all the tissues, as seen in the short foot familiar in old hip cases.

When pain attends hip-disease, it is commonly definite, and referred to the immediate neighborhood of the joint; but sometimes it is also felt down the front or inner side of the thigh, and even as far as the knee. This distant pain is supposed to be due to irritation of the obturator nerve, the distribution of which in the hip- and knee-joints and down the thigh corresponds with the distribution of the pain. Even in the absence of pain in the hip-joint, pain down the thigh or in the knee may be felt, and might withdraw the surgeon's attention from the joint concerned, were it not that the traditional interest attached to "pain in the knee" has become established, in literature and practice, as a symptom of hip-disease. The pain accompanying hip-disease is often persistent and prolonged, and even when it has ceased to be constant or frequent, is easily reproduced by slight movement or pressure. It is probable that acuteness of pain in the hip-joint is a sign of tension. This tension may be capsular or interosseous. Persistent and prolonged pain, described as dull aching or boring in character, often attends cases in which the bones are primarily affected,

and in which afterward shortening of the femoral neck or absorption of the head is manifested by the altered position of the great trochanter, and by a shortened limb. Tension or at least irritation in parts inflamed may be brought about by their movements; hence the great pain experienced in many cases of inflamed joint previous to their fixation by a suitable splint, and the converse, the early relief experienced on the mechanical attainment of immobility.

All this may occur without abscess, and the result may be a complete return to soundness, in the sense of recovery from inflammation, the disappearance of all pain and tenderness, the maintenance of strength and of a large amount of mobility. But there may easily be left some flexion-deformity, and usually some limitation of motion, especially if mechanical treatment has not been very thoroughly persisted in for a long time. More generally, however, in cases of prolonged pain and primary disease of the bones, an abscess forms, and effects a great and serious change in the prospects and management of the case, although such an abscess may become absorbed quietly, with or without aspiration.

The "shortening" alluded to as a deformity is most important, and always indicates defective growth or loss of substance in the femur. It may in later stages be considerable in amount, and will then usually be found to indicate partial or complete luxation of the hip, rendered possible especially by the absorption of the rim of the acetabulum. Such luxation may occur despite careful treatment. There are, however, many cases in which stiffness in the flexed position, with or without other fixed attitudes, produces an effect of shortening that on close investigation is found to be apparent only. To distinguish between "apparent" and "real" shortening is of importance, but this cannot be attained by merely measuring the length from the anterior pubic spine to some fixed point in the limb, such as the tip of a malleolus, unless the relation of the limb to the pelvis is the same on both sides. For ordinary purposes the amount of real shortening, or its absence in the event of apparent shortening, can be detected at a glance by placing the limbs "symmetrically," as referred to above in the estimation of flexion. These adjustments are effected by manipulating the limb on the diseased side until the pelvis is placed quite evenly. Then the sound limb is put in the same position as that in which the other is fixed, and by comparing the two sides their length is found to be identical in cases of apparent shortening, and the amount of true shortening is accurately seen in cases where it exists. For exact measurement, however, and complete demonstration, "Nélaton's line" is valuable. This is indicated by laying a tape on the outer side of the limb from the anterior superior iliac spine to the ischial tuberosity of the same side. In a sound hip, or in one unaffected by shortening, the tip of the great trochanter lies just below this line. In the event of shortening, the amount will be shown by the altered situation of the trochanter in relation to Nélaton's line. For this demonstration the patient has to be turned over on the sound side.

Diagnosis.—From the account just given under the head of Symptoms, it is evident that the diagnosis may be easy or difficult according to circumstances. Many cases run their course without abscess or any signs of liquid effusion. Some are actually painful and disabling, and attract attention early; while others are milder in their course, and more or less recovered from, even if untreated, and result in flexion-deformity and stiffness. Mistakes in diagnosis may be made

not only by beginners but by persons of ripe and varied experience. The most usual mistakes are the confusion of hip- and spine-disease above referred to, the failure to recognize acute sprains or fractures of the femoral neck, and occasional failure to detect congenital hip-dislocation or coxa vara.

Principles of Treatment.—The treatment of hip-disease has the following objects in view: (1) immobilization of the joint; (2) separation by traction of the joint-surfaces; (3) the correction of flexion or other malposition; (4) the treatment of abscess. In early cases the importance of rest in bed must always be kept in mind. Even if no appliances be at hand, this resource need never fail, especially in the presence of pain or tenderness. Its employment is obviously dictated by common sense, and cannot be dispensed with until all pain and tenderness are gone. The application of a splint, without confining the patient to bed, should seldom or never be resorted to until the surgeon has had some experience in its use, enabling him to judge which cases are fitted to move about from the commencement. Not only in early cases, but where there is double hip-disease, and in cases at any stage where there is much pain or tenderness, marked deformity or rapid progress, with or without abscess, bed treatment is indicated. Almost invariably, however, the recumbent position has to be supplemented by some mechanical arrangement that fixes the limb and trunk in line. The more completely and rigidly this fixation is attained, the more effectual will the treatment be. For this purpose the long splint of Liston has often served, and up to about 1874 was the chief resource in the British Isles.

In the case of infants the single long splint is almost useless, because the patient rolls over on the side, in which position flexion of the hip-joint is not prevented. To secure proper immobility, a pair of long splints attached by a cross bar at each end, so as to constitute a stiff frame, keeps the patient still enough to attain the object in certain cases. Still better is a fixation-frame to which the patient may be strapped. Such a frame may be made of light gas-pipe, joined at the corners with

FIG. 354.—Bradford's fixation-frame.

ordinary right-angled gas-fitters' joints. It should be from two to four inches longer than the patient, of a width about equal to that between the shoulder-tips. It is covered with stout drilling, tightly stretched, as shown in the illustration (Fig. 354). Such a frame gives a means of fixation for the patient's body, and makes it possible to move him without stirring up the joint. Traction is applied by weight and pulley; a hold on the limb is secured by adhesive plaster strips running

well up the thigh; the weight used is from 4 to 10 pounds. Traction is made in the line of deformity, if deformity is present; if flexion is present, the leg is meanwhile supported on an inclined plane. Under this treatment reflex spasm, the usual cause of deformity, relaxes, and the apparatus is gradually lowered till the traction is exerted in full extension.

The Thomas hip-splint is also used for bed treatment, though it does not in its usual form provide for traction.

The great mechanical value of Thomas's hip-splint rests in its application behind the limb and the trunk, in such a way as most effectually to oppose all tendency to flexion. It is made of flat iron rod stiff enough to resist the muscles of the patient, but not too stiff to be twisted or bent forcibly by the surgeon or instrument-maker. In its single form it is slightly padded and covered with leather (Fig. 355). For infants and young children the double splint is much the best, and fixed padding can often be dispensed with, being replaced by a large loose flat pad enclosed in basil leather for the back (Fig. 356), while the limbs are protected by a roll of cotton wadding bandaged on. The modification of the Thomas splint by Robert Jones (Fig. 358) provides not only for fixation but for traction as well, and a certain amount of abduction counteracting the usual adduction and flexion-deformity.

FIG. 355.—Thomas's single hip-splint.

FIG. 356.—Thomas's double hip-splint ready for application; loose pad for the back *in situ;* shoulder-braces of bandage passing through leather tubes to go over the shoulders.

The vast majority of cases of hip-disease, however, need bed treatment for a short time only, or at infrequent intervals, and can be well

treated by ambulatory splints. The first requisite of such a splint is that it relieve the hip of weight; the second, that it fix the hip. Beyond this there is good reason to believe traction on the leg of definite value. The splints most in use are modifications of those of Thomas and of Taylor. The Thomas splint is more effective in fixing the joint and limiting flexion; it is, however, somewhat cumbersome, does not afford any traction beyond the weight of the limb, and does not really insure rest to the hip even where a high sole on the other foot is used, for children are very likely, where the joint is not tender, to use the foot

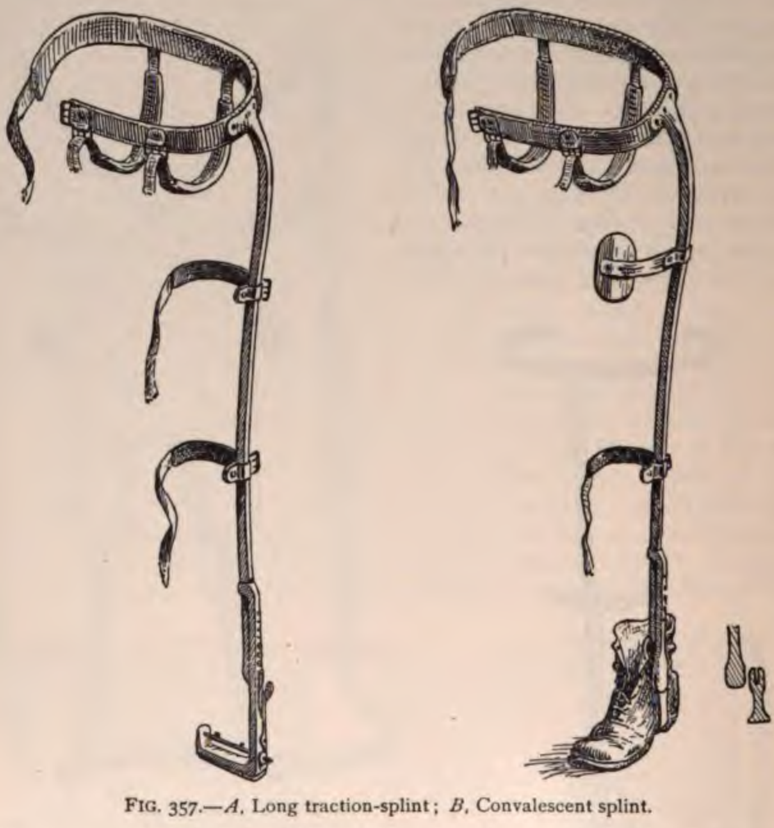


FIG. 357.—*A*, Long traction-splint; *B*, Convalescent splint.

despite any apparatus. The Taylor splint fixes less well, but with proper application it is possible to secure good traction and to prevent absolutely any use of the limb. With either splint the high sole and crutches should be used.

If pain persists in spite of a well-applied splint, it will be due to a persistent course of the disease, especially in the bones.

In late cases, if the flexion is great and the stiffness is marked, though not extreme, while pain is absent, and the case is chiefly one of deformed attitude and resulting chronic lameness, rest in bed, with traction and prolonged treatment with the extension-splint, will effect

a gradual straightening, and ultimately greatly improved progression. This gradual straightening is a spontaneous process unattended by any mechanical force on the part of the surgeon, who merely "takes in the slack" as he finds it. It is not always painless, and may be a source of much aching and sleeplessness to the patient during the first few days. This pain is due to the stretching of muscles which have become shortened during the maintenance of the flexed attitude, and also, perhaps, to a similar stretching of shortened capsule.

A very important question then arises as to how long treatment must be continued. It must be obvious that treatment should continue until the symptoms have disappeared and do not return; but the symptoms sometimes do return shortly after remitting the treatment. Practically, it is not safe to omit the splint until a year or two after muscular spasm has disappeared. During this period, however, a convalescent splint (Fig. 357, *B*) may be worn. After the application of such splint the patient should be carefully inspected at intervals, to see whether any flexion-stiffness, pain, or increased tenderness have returned. The return of any symptom should be met by the re-application of the splint previously worn, or perhaps by confinement to bed, and treatment is to be continued until all symptoms are gone and fail to return before resuming the convalescent splint. The removal of the splint becomes just as much a matter of experience as its original application. The evidence of complete resolution is the absence not only of all pain and tenderness, but also of all stiffness or return of deformity. The patient must be able to extend the hip-joint fully while lying down on a flat surface with the sound limb bent completely on the trunk. In practice, however, perfect results are rare. After a prolonged adoption of the straight position in the splint, and the increase and improvement of locomotion this affords, one of two things may be expected to result—either the occurrence of permanent stiffness in the straight attitude, or the restoration of movement in the joint. The permanent stiffness of the hip-joint either by bony ankylosis, which is not frequent, or by fibrous adhesion affords, when attended by the straight position, a complete and almost perfect locomotion, which in walking can be effected without the slightest limp, if there be no shortening. If in treating a case no relaxation of the flexion occurs, if bony ankylosis be otherwise ascertained to exist, the femur may be divided at or above the great trochanter.

FIG. 358.—Thomas's double hip-splint as modified for extension and abduction on the left side; perineal band on the right.

The ideal treatment of abscess with accompanying hip-disease would naturally be aseptic incision, with or without flushing with hot water or weak antiseptic solutions, and with or without immediate suture after filling the cavity with iodoform-and-glycerin emulsion. Such treatment should be preceded by the application of a splint, in combination with which the necessary dressings can be applied. Incision of abscess requires bed treatment for some time afterward for best results.

The opening and satisfactory healing of abscesses by aseptic incision and dressing, without removal of bone, may result in all that can be desired, leaving the limb useful and unshortened, as in resolution of

FIG. 359.—Left hip-disease following typhoid in a man aged thirty-six. Put up under extension and abduction, after osteotomy of the neck of the femur.

the disease without abscess. If bony ankylosis or stiff fibrous union result in the straight position, the necessary movements occur through the flexibility of the lumbar spine. Similarly, the spontaneous bursting of abscess, and even the continuance of sinuses, may result in spontaneous healing, with or without shortening, flexion, or other deformity. But such sinuses may persist, and impair the health or lame the patient. Secondary excision, performed from the front, may result beneficially, and after healing may be followed by complete recovery of health and strength, with shortening, but often with considerable motion.

Although pain, tenderness, and stiffness quickly disappear in many cases on the application of the splint, there are others, more or less acute, in which the expected relief is greatly delayed or fails to occur,

the case going on from bad to worse. The advance of the tubercular process often accounts for this, and the subsequent shortening in cases that eventually get well proves the fact of absorption in the head or neck of the femur. In other cases that have still recovered with shortening, abscess has formed and has been successfully treated, the process never having been acute. Others, again, had early persistent pain, eventual relief, the late formation of abscess, and its successful aspiration.

Excision of the joint is best done at the front or side, which is more accessible for dressing purposes, while the tissues behind are preserved

FIG. 360.—Multiple osteomyelitis, that of the femur affecting the hip-joint; ten years' duration; patient aged sixteen.

unwounded for the application of the splint. When undertaken comparatively early, before the surface has broken, the tubercular process has a good chance of being eradicated, and the part restored to soundness and utility more speedily than after the formation of sinuses. There is necessarily some deformity, owing to the inevitable shortening.

The pathological condition in the cases to which early primary excision is applied differs considerably from that in which the operation is performed "secondarily." In the former class of cases there is the

unbroken surface, and the chief features of disease are the softened, carious, and caseous state of the cancellous bone in the head and neck of the femur, and the swollen and shreddy condition of the surrounding capsular ligaments and other soft parts. There may be abscess, but it is often more serous than purulent in character. The object of every such operation is to remove all tubercular material, inflammatory exudation, and portions of devitalized or half nourished tissues adjacent, the removal of which by absorption is not, indeed, always impossible, for such process must often occur, but the presence of which at the best greatly delays the reparative process, and in the event of bursting or incision may be attended with burrowing sinuses and secondary infective suppuration. Firmer and sounder tissues are left in contact with each other, and in spite of the deformity resulting from removal of bone, a much quicker local repair is obtained than by the efforts of nature, while the patient's health is speedily restored, or often not actually impaired. Moreover, the healing of the parts sometimes results without suppuration, febrile reaction, or delay of any kind.

In the cases to which "secondary excision" is applied there may have been partial repair, but sinuses are established leading to the remains of the joint, and perhaps to the surface or interior of carious bone. In other cases steady increase of symptoms despite careful treatment is the indication for excision. The object of excision is to open up the burrowing channels of local infection, and to attain healing by the granulation of the cavity that remains. The effect of operation in some cases is as speedily beneficial as in the removal of diseased bone in other parts away from joints; but in other cases, where the operation is performed on emaciated and anemic subjects, the risks are great though necessary, and the recovery is sometimes slow.

Late excision is indicated by the condition of the joint *per se*, early excision often in adults, and where thorough treatment is impossible. The question of the selection of cases for early excision is still a disputed point. Some surgeons frequently employ this measure; others, almost never. In certain cases where the whole hip region is involved and riddled with sinuses, especially where there is an extensive osteomyelitis of the shaft of the femur, amputation is indicated. Excellent as the results of late excision often are, in some cases the operation is wholly unsatisfactory.

In cases of chronic deformity attended with much shortening, flexion, and adduction, with up-tilted pelvis, Robert Jones has still further improved the treatment by action of the combined hip- and knee-splints, modified as in the extension treatment of quickly deteriorating early hip-disease. With a fine saw he performs antiseptic osteotomy of the femoral shaft very obliquely about the great trochanter, and then puts up the limb in the abducted position, under extension, during the progress of union. As in early caries, the extension is maintained, and occasionally re-adjusted, until the limb is firm and strong. The effect of the abducted position is to tilt the pelvis down on that side, and so to make up for some of the shortening previously existing.

Two years ago the writer succeeded admirably in such a case in a man of thirty-six, much deformed after typhoid. The left hip was ankylosed, adducted, flexed, and rotated in, the skin fortunately being unbroken, and the tissues healthy. Osteotomy of the femoral neck was performed with a chisel driven straight through the skin above and behind. The limb was put up under extension and abduction. The wound healed by first intention, and all deformity was got rid of in a very few weeks, without impairing the patient's health in the least. In this case no special appliance was used. The sound side was fixed in an ordinary single hip-splint. Extension was applied after osteotomy on the affected side by means of a Thomas's knee-splint. Abduction was kept up by means of a small knee-splint

tied to each ankle, so as to keep them apart. The accompanying illustration (Fig. 359) is from a photograph taken after seven weeks, previous to letting the patient up in a left single hip-splint. He has progressed well ever since, and all deformity is gone.

Where there is flexion-ankylosis or flexion with adduction, the subtrochanteric osteotomy of Gant is also of service. Osteotomy of whatever description is rarely to be applied except in cases where there is firm ankylosis; other cases are usually more amenable to other treatment, either conservative treatment or excision.

Osteomyelitis is sometimes a cause of hip-disease, as well as disease of other joints.

Simple traumatic inflammation of the hip may occur. The treatment in Thomas's splint is both simple and speedy, resulting in complete recovery in a very few weeks.

DISEASES OF THE KNEE-JOINT.

Affections of the knee-joint are chiefly inflammatory, and may be anatomically divided into three classes: 1. Synovitis; 2. Capsular arthritis; 3. Osteo-arthritis.

Synovitis.—By synovitis is usually understood an effusion, more or less liquid, into the joint-cavity. The effusion may be pure blood, serum, or pus. Since pneumatic aspiration with antiseptic precautions has come into vogue, the nature of the effusion can be harmlessly and often beneficially investigated. Effusions of blood are commonly entirely liquid, but sometimes coagulate shortly after issuing. Effusions of serum, so-called, also frequently undergo partial coagulation of thin, yellowish fibrin. Effusions of pus, promptly withdrawn by aspiration, after efficient fixation in the straight line, are sometimes cured after one or more, sometimes very few, tappings. The bacteriological examination of the pus shows micrococci, indicating the character of the inflammation, which may be pyemic or gonorrheal. The differential study of these conditions is favored, and the treatment often expedited, by merely tapping; in fact, much clinical light is thrown upon the effusions into the knee by tapping. In aspirating joints the trocar should not be smaller than a No. 2 or 3 catheter (English scale), and may be required as large as a No. 4 or 5 or larger for some purposes. Effusions into the knee are easily seen and felt by the bulging of the joint-cavity, everywhere in some cases, but frequently in the suprapatellar region alone. This condition may exist without severe symptoms, coming on gradually and almost imperceptibly at times, and then causing no more inconvenience than a weakening of the knee and diminished activity of the limb; but in other cases severe pain and total disablement are conspicuous, with or without acute fever. Synovitis may be caused by a sprain, when it may come on immediately or after a few hours, by acute or chronic rheumatism, gonorrheal rheumatism, or tubercular inflammation. It may also be set up by the irritation due to popliteal aneurysm. When resulting from sprain or other sudden injury, the fluid effused may be pure blood, but is usually serous. The joint in synovitis may or may not be painful, tender, and disabled, and the patella separated from the femur by effusion.

Many cases of synovitis of the knee tend to recur persistently, even

where they cannot fairly be called chronic. In some of these cases the underlying condition is a stretched capsule resulting from the first attack, often associated with a lack of support from muscles which have never recovered fully from the atrophy occurring with even acute synovitis. In other cases a slipping patella is the cause, and calls for appropriate treatment, either by protective apparatus or, if obstinate, by an operation to take up slack on the inner side of the capsule. In other cases, however, more common than either of these conditions, we have to deal with luxations of the semilunar cartilages. This condition is important, not only from its relatively common occurrence, but from the frequency with which it is overlooked. In a knee where either cartilage has once been luxated a slipping may occur on the slightest provocation, and may give rise to severe synovitis. If the cartilage be still displaced (evidenced by a painful "locking" of the knee when full extension is attempted), it is possible to reduce it by the classical method: flexion and traction, rotation and extension; but even after entire subsidence of the acute symptoms the trouble is likely to recur, and may eventually necessitate removal of the offending cartilage.

Some cases of synovial effusion are apparently of syphilitic origin. It has been asserted that "symmetrical synovitis" of the knees in young persons is often to be accepted as evidence of inherited syphilis. Be this as it may, the writer has met with obstinate synovitis where a history of syphilis has existed, and where thickening of the capsule and chronic orchitis, suggestive of gummatous enlargement, have yielded to antisyphilitic medication. The evidences of syphilis in cases of synovitis are, in the opinion and experience of the writer, both rare and difficult to prove; but they would appear at any rate to be met with occasionally.

Attacks of synovitis, with or without the thickening that indicates general capsular arthritis, are not infrequently found associated with a present gonorrhea or gleet, or a history of a recent attack. Such cases well fixed in a proper splint may be rapidly relieved, but if not, it is well to perform aspiration after fixing the limb. If the temperature is raised, suppuration may be suspected, and by this operation readily found. The number of tappings depends upon the effect. One, two, or three, at intervals of twenty-four or forty-eight hours, or of several days, will commonly suffice. The urethral discharge meanwhile should be treated. Gonorrheal synovitis of the knee is highly amenable to tapping, and commonly recovers quickly; but the prognosis must always be guarded, as fibrous ankylosis may sometimes occur in spite of all treatment. Incision and joint-irrigation have given some good results.

In treating a case of synovitis it is important to keep the limb rigid and straight. A conventional method which is not infrequently resorted to consists in ordering the patient to bed and directing the application of fomentations until the pain ceases or recovery ensues. This method is often a sheer waste of time, and, moreover, by delay aggravates an acute and often quickly curable synovitis into a subacute or indolent chronic condition. There are cases of a rheumatic or gouty character in which fresh air, exercise, frugal feeding, and perhaps local massage are of importance, while the fixation of the joint is not. Ordinarily, fixation on a splint, with some compression, is necessary.

As regards the splint, the most effectual of all is Thomas's knee-splint made of iron rod. The variety known as "bed-splint" is applicable to either limb, having a symmetrical padded oval ring embracing the top of the thigh, and a bar down each side of the limb, extending below the foot, where the bars are connected. For patients walking about, the splint is made shorter and the side bars are disconnected below, but each is turned toward its fellow and made to clip in a hole in the heel of the boot. In that form it is called the "calliper." Another form of "walking splint" (Fig. 361) is slightly different from each of these in its lower end, which projects beyond the foot and ends in a "patten" or ring which rests on the ground. Attached to the boot on the sound side is another patten, to equalize the length of the two limbs. In this fashion children and young people can walk without bearing any weight on the diseased limb, which hangs suspended in the iron frame that bears the weight, as the patient sits on the upper oval ring. In severe and many other cases the use of Thomas's splint in one form or the other enables the surgeon to succeed where otherwise the joint would go on to destruction. In simple traumatic cases a simple knee-splint will suffice.

FIG. 361.—Photograph made for H. O. Thomas in 1875, showing his knee-splint with square end. Compensating patten on opposite foot. The "patten end" of the splint has been used since that date.

Where the tenderness and disablement are not great, and the patient can be made to understand the utility and importance of voluntarily keeping the limb stiff and straight, the joint may be fixed with wide strapping from the middle of the calf to the middle of the thigh.

For this purpose also sheets of brown paper spread with a mixture of pitch and resin, thinned with benzolin, make very useful plastering material, which can be applied in strips from 3 to 5 inches wide. The result is an adhesive, firm, light casing, having a neat exterior, that can be readily torn off when changed or discontinued.

Capsular Arthritis.—Capsular arthritis is a general inflammation of the capsule, and may occur in cases of sprain or other injury, with or without synovial effusion. The peculiarity about capsular arthritis is that evidently the capsule is affected by the inflammation and is thickened thereby, whereas in synovitis there is effusion without such participation and thickening. Tubercular arthritis is usually of this kind, though practically always the primary focus is in the bones. In

some cases a swelling occurs in some corner of the joint, protruding the skin, and giving to the finger a feeling of elasticity, so much so that aspiration or incision may be practised in the hope of letting out fluid, sometimes with and at other times without such issue. Anatomical and surgical experience show that in tubercular infection there may be any degree of local or general edema, puffiness, swelling, in the depths of which may be miliary tubercles, gelatinous edema, granulation tissue, patches of necrotic caseation, or suppuration. Such swelling often comes on slowly, painlessly, and without the collective attributes of acute inflammation, for which reason no doubt the old term "white swelling" was naturally applied to it.

Treatment.—A case of early arthritis of this kind may sometimes rapidly improve if the joint be fixed and the patient's weight be taken off it by the use of the longer walking splint with patten end and additional short patten on the opposite foot. The need for careful fixation by Thomas's splint is indicated in capsular arthritis, which itself may come on in aggravated synovitis that does not yield at first to treatment. After recovery and discontinuance of the splint, synovitis may occur in the joint, and disappear again on resuming the splint. Sometimes the inflammation is "gummatous," and will yield to rest and mercurial medication with or without potassium iodid; it may be added, with or without a splint.

Osteo-arthritis.—"Osteo-arthritis" or "articular osteitis" occurs in the tubercular process which first affects the growing ends of bone and then implicates the adjacent joint. There may be continuous dull or even severe pain in the affected bone, and abscess may form outside or may invade the joint. Osteo-arthritis may also occur in association with acute, and especially with chronic, osteomyelitis, the latter of which, from its slow and often painless progress, may closely simulate the appearances of tubercle.

Tumor.—The existence of sarcomatous "tumor" in the interior of the femur or tibia, at the knee, may be attended with a similar aching that is indistinguishable from that of osteitis, in both of which diseases there may be no alteration in size during the period of observation. In other cases of tumors that give way and burst into the joint, there may be many of the appearances of chronic white swelling. The very relief afforded by Thomas's splint to a patient still walking about has been known to mask a case of malignant central tumor of the femoral condyles, where only intense aching pointed to the great probability of a central disease of the bone. But the disease is supposed to be osteitis, and is only discovered to be sarcoma on performing excision of the end of the bone. In a case left to go about and bear weight on the affected bone, fracture of the bone and rapid diffusion of the tumor in and about the knee-joint usually occur at an early period. Such cases may be recognized by the absence of tubercular history or tendency, by the occasional existence of pulsation in the swelling, or by the sudden giving way of the limb on exertion, indicating fracture of the adjacent bone in cases where that event occurs. In either tubercular arthritis or tumor of the knee-joint there may be antecedent injury or the reverse, and the resemblance between the two conditions may be quite sufficient to cause perplexity, especially where, in the case of tumor, the region is

symmetrical and oval, as in typical white swelling. The conditions are most apt to be confounded when the likelihood of tumor is overlooked, so that a careful analysis of the conditions will commonly result in a correct diagnosis.

Treatment of Knee-joint Disease.—The treatment should be mechanical in the vast majority of conditions. In synovitis, whatever be the cause, mechanical treatment is called for at once. If acute and disabling, the patient must be kept in bed. In the absence of the best kind of splint, excellent fixation may be attained in bed by a variety of temporary expedients, such as canes, strips of wood, or other articles of sufficient length, firmly bound to the limb over a suitable padding of cotton wadding or thickly folded.sheeting. Such temporary expedients are enough sometimes to keep the limb at rest while the patient sits or even walks about; but the appliance in which efficient fixation can be most easily and securely attained is Thomas's splint.

Whether a case be treated in bed or going about must depend upon the sensitiveness and the circumstances of the patient. As a rule, in synovitis he can bear his weight on the limb when fixed straight, and sometimes in capsular arthritis also. For this reason it is seldom necessary to have Thomas's splint longer than the limb in cases of this kind. At first Thomas took the weight off the knee in all cases, but afterward he simply fixed the joint in synovitis, and eventually found increased use for the calliper splint in mild cases of capsular arthritis, many cases recovering, after previous use of the longer splint, with compensating patten on the other foot. It is, moreover, possible to take the weight of the body from the affected limb in walking by merely making the calliper splint of *full length*. The ischial region then rests on the top ring, on which most of the body's weight is then borne at each step.

It is not to be supposed that all cases of synovitis can be cured with perfect mechanical treatment, even when supplemented by aspiration. Cases of suppuration may require incision. Some are so virulent that total destruction of the joint results, and amputation is required to save life. Others go on to firm ankylosis of the joint, in spite of all attempts at antiseptic management. These are usually cases of peculiar infection, not limited to suppuration, but attended also with necrosis of connective tissue. They may be idiopathic or traumatic. In the former event, broken-down constitutions are commonly a favoring condition; in the latter, wound of the knee-joint, imperfectly investigated or otherwise subjected to mixed infection. When once obstinate suppuration of the knee-joint is established, ankylosis is almost certain to result if the patient and the limb survive. In puncture or other wound of the knee-joint, and more especially if that event be merely suspected, the only wise course is to explore the wound under an anesthetic, carefully fix the limb straight, and apply an antiseptic dressing to the part, preferably without closing the wound.

Sometimes, in chronic synovitis without suppuration, free incision of the joint is required. Such operation is not to be lightly undertaken, and only after proper arrangements for antiseptic management, and the most careful adjustment of the splint, which for this and all the other purposes of exactitude should be that of Thomas.

Cases of tubercular arthritis can with advantage be mechanically treated in Thomas's splint at first, and in the early stages with bed treatment as well. Many cases do tolerably well with simple fixation in a plaster-of-Paris bandage, but this is not an advisable treatment. The usual ambulatory treatment should be by the long Thomas splint, preferably supplemented by a light plaster-of-Paris bandage which prevents flexion. Traction may be applied as in hip cases, by means of adhesive plaster strips, which in this case should not extend above the knee. Traction does not seem, however, to be as essential in the treatment of the knee as it is in hip-disease. The high sole and crutches should always be used till the convalescent stage is reached. Slight cases, especially in children, yield remarkably well, and often get quite sound; but in the event of abscess the case is different. Even then, in children, sound healing may occur after bursting or incision. The healing is sometimes spontaneous without any attempt at antiseptic dressing; but in spite of this the dressing should be used whenever the condition is known to exist. In adolescents or adults it often happens that abscess forms in one corner or other of the joint, and it is well in such cases to ascertain quickly whether or not the abscess comes from the joint, and to perform excision early, before secondary suppuration has occurred. It is useless to temporize with tubercular arthritis in adults or adolescents when suppuration exists or when the articular surfaces are eroded. Even in the absence of suppuration, a puffy, pulpy synovitis, unless distinctly relieved by mechanical treatment and evidently diminishing, should be submitted to operation by excision or amputation. In children, however, mechanical treatment may well be long persisted in. When improvement occurs, the rule is that the splint with the patten and the high sole on the sound foot be worn till reflex spasm disappears, then supplanted by the calliper splint during the long period of protection which is necessary here as in hip cases.

Not infrequently, even with fair treatment, some flexion of the knee results, and in the less successful cases subluxation of the tibia backward may occur. For this reason reduction of flexion-deformity in the knee, especially in the later cases, is difficult, and, where forcible reduction is advisable, special apparatus is necessary to correct the subluxation together with the flexion. Where actual ankylosis has occurred, with marked flexion, either osteotomy near the joint or excision must be resorted to.

Excision of the Knee-joint.—In excision the operation should always be planned, if possible, before the surface is broken by previous operation. Careful aseptic puncture by aspiration need not vitiate the condition most desired in excision, nor even exploratory incision, if performed within twenty-four hours under stringent antiseptic precautions. Having opened the joint by a transverse incision passing between the patella and tibia, the ligaments are divided, and a slice sawn off the femur and tibia in the horizontal plane of the joint, so as to result after union in a perfectly straight limb. All suppurative, caseous, and tubercular tissues are carefully removed, even to the extent, when necessary, of complete dissection away of the capsule and of the whole of the patella. After arresting the hemorrhage and applying copious

irrigation with hot water, the bones are placed together, the integuments closed by a few sutures, and the wound enveloped in carbolized cyanide gauze. The writer has always used Thomas's splint, with which the desired fixation can be attained. A long, wide, hollow splint of sheet iron, moderately padded and enclosed in mackintosh waterproofing, is laid behind the limb, from the top of the thigh to the middle of the calf, slung to the bars of the Thomas's splint. The foot is enclosed in antiseptic gauze, covered with plenty of cotton wadding folded round it in long strips, and bandaged firmly to the bars of the splint in an easy but immovable position. The skin and calf are enveloped in similar material, soft and thick, and bandaged permanently to the splint. For several inches above and below the wound are placed dressings of cyanide gauze, which can be slipped away and freshly interposed a day or two after operation, and occasionally afterward, without disturbing the general arrangement of the splint or the quiescent attitude of the limb. Above and below the wound-dressings, between the posterior waterproof splint and the limb, is placed some sublimated wood-wool sheeting, so that all may be comfortable and free from damp, or in a position to dry readily by evaporation. When the conditions are favorable, good healing of soft parts and firm union of bone quickly occur. Sometimes a stitch-abscess or even a tubercular granulation or abscess may form, without detriment or serious delay, and can, if necessary, be dealt with by a minor excision or scraping. But the rule is quick recovery, very like what occurs in a well-conducted aseptic compound fracture, with even no more disturbance than occurs in simple fracture. In emaciated adults having profuse suppuration or septic sinuses connected with the knee-joint, it is commonly safer to resort to amputation. Even here amputation should not always be done, and the writer has succeeded with excision when the risk of failure or even death was encountered. In such cases months instead of weeks may be required for the necessary healing, and the expected risk should not often be faced except at the urgent request of the patient, and with a reasonable expectation of success.

The object of excision is to get rid of the tubercular or other inflammatory process; and as this cannot be done while retaining the surfaces and movements of the joint, some bone has to be removed, even if not actually diseased, in order to bring about the most favorable and durable ankylosis. Even when the bone-surfaces are involved, it is only superficially, as a rule, and no more than a thin slice has usually to be removed. Excision is also required sometimes in order to straighten a limb ankylosed in the flexed position, although osteotomy is usually possible, with good results.

DISEASES OF THE ANKLE-JOINT.

Synovitis may occur from a simple sprain, and in milder cases, if treated immediately by strapping and bandage as employed by Pagan Lowe of Bath, will recover more or less quickly, under certain conditions, without confinement to bed. In severe cases more complete rest in plaster, usually in bed as well, is necessary to speedy repair A neglected sprain of the ankle may be a most tedious affair, and in

delicate persons may go on to tubercular arthritis, suppuration, and fatal phthisis, or in other cases to destruction of the joint and the necessity of amputation.

Certain cases of acute or subacute **arthritis** of the ankle are of gonorrheal origin, and are remedied by early fixation in a suitable splint.

Tuberculosis of the ankle is usually primary, and, save in the case of the os calcis, the process rapidly involves the whole tarsus. Early tubercular arthritis of the ankle, without suppuration, may be fittingly treated by Thomas's skeleton splint of iron rod reaching up to the calf, or by a plaster-of-Paris bandage. The addition of Thomas's knee-splint, for progression, is an invaluable help. The writer has no experience of excision of the ankle-joint, having treated advanced cases by amputation, either above or at the articulation. The operation of **excision** should, however, be considered, and, especially in children, has given good functional results. The time required for after-treatment is long, and in children it is more often justifiable to undertake a long course of treatment than in adults. Enough good results from excision in children have been reported to make the operation distinctly worth while in suitable cases. In adults amputation should be the usual resort in advanced tubercular disease of the ankle-joint. In differential diagnosis arthritis deformans, flat-foot, and the other static disorders are especially to be considered.

DISEASES OF THE SHOULDER-JOINT.

Disease of the shoulder-joint seldom takes the form of synovitis. Whether it be that the joint is not ordinarily capable of much distention (it has been supposed that the capsule easily gives way where the biceps tendon traverses it, and lets fluid escape into the surrounding tissues), or whatever be the explanation, inflammation of the shoulder is hardly ever attended by fluid distention.

Sprain of the Shoulder.—Puffy edema in sprain or arthritis of the shoulder may easily occur, and is not to be mistaken for synovial effusion. In the examination of an injured shoulder or upper arm it is often advantageous to examine in narcosis; if this is not done, it is of great practical assistance to the surgeon and a comfort to the patient, after stripping, to flex the elbow and sling the wrist to the neck, for which purpose a folded handkerchief or other triangular bandage is the most handy. The weight of the forearm is thus transferred to the neck, and taken off the upper arm and shoulder, which latter parts are then most easily and painlessly examined. With one hand on the shoulder and the other holding the elbow, gentle movement can be made to distinguish between fracture of the clavicle or upper end of the humerus and sprained shoulder. In the latter affection creaking of the capsule may give a sensation something like crepitus. In the treatment of sprained shoulder the position just described for the examination is continued till the part is well, the wrist being slung to the neck at a convenient height and the arm strictly confined to the body by a wide bandage around both arm and body, immediately above the elbow. This prevents movement in the shoulder-joint, which must further be protected from

pressure by keeping the patient from lying on it when in bed. A few strips of plaster may be laid on the shoulder, in the event of great tenderness, both horizontally and vertically. This will fix the skin and help to secure comfort and rest. There is no need of any splint or casing of leather, gutta-percha, or mill-board, as all the necessary protection can be quickly applied in the form of many strips of plaster. If these be made of brown paper rendered adhesive by a solution of pitch in benzolin, the skin is kept aseptic and free from much itching. To cool the shoulder, moreover, the paper plaster may be moistened after application, with grateful effect. In chronic inflammation of the shoulder-joint there is more or less tenderness, but especially stiffness, recognizable from behind on passive abduction of the elbow while the wrist is slung to the neck. In proportion to the stiffness, the scapula moves with the upper limb in abduction; but during the progress to recovery the amount of this stiffness gradually diminishes. In neglected or obstinate cases the flexed and slung limb has to be tied up against the trunk for months, but may often be got well with perseverance. In some cases passive motion is of great value.

Arthritis of the shoulder in cases of tubercle or osteomyelitis is frequently attended with abscess, which may burst and leave sinuses, commonly opening before or behind the surgical neck of the humerus. Operation in these cases should be strictly limited to the necessities of the case. After incision, necrosed or carious bone can be dealt with in osteomyelitis by removal of sequestra or gouging of surface, without interfering with the articulation in every case. Such cases may at first be easily mistaken for tubercle, and they sometimes cause surprise at their quick and easy recovery. But whether in osteomyelitis or tubercle, if septic sinuses communicate with the joint, and the articular surfaces of the bones be eroded, it is best to turn out the head of the humerus and remove it by excision. A vertical incision on the front of the joint is the best; but the position of sinuses may dictate a different direction in which to open the joint, such as the older-fashioned deltoid flap raised up from below, or some other that the exigencies of the case may suggest. During the healing of the wound the limb should be slung as above described. This device, in cases not requiring operation, was practised by the late H. O. Thomas.

In **acute rheumatism,** transitory inflammation and pain in the shoulder-joint occur, but the recumbent position, without appliance, is commonly sufficient for the needs of this particular joint.

DISEASES OF THE ELBOW-JOINT.

Sprain.—The elbow-joint is frequently sprained by falling and otherwise. The result is pain, heat, swelling, and disablement, the characteristic symptoms of inflammation. Synovial effusion may sometimes occur, and the writer has seen it in chronic inflammation. The moment an elbow becomes acutely inflamed, the pain hampers the movement and seriously incommodes the patient. If laid in bed on a pillow, the painful limb is disturbed at each change of position. If conventional routine treatment be adopted and fomentations applied, without the simple precaution of fixing the limb in an

immovable easy position, days may be spent in "taking down the swelling," as this process is called. The best plan is to strip the patient to the waist and sling the arm to the side, with the wrist firmly and comfortably attached to the neck by a soft folded handkerchief or other form of triangular bandage. If attended to immediately after injury, a rectangular position or flexion to a smaller angle may be found a speedy relief; and if there is no fracture, all that is required is to continue this attitude without change, applying the clothing as may be most convenient over the limb thus fixed to the body. If, in addition, fomentations be applied, well and good; but if the limb has been hanging straight or at an obtuse angle for many hours, the attainment of the flexed position will be painful at first. It can usually, however, be sufficiently bent, by gradual and gentle manipulation for a few minutes, to attach the wrist to the neck and keep the limb against the trunk. This secures a position of rest which can be maintained at a right angle or lesser angle pending recovery. No splint is required, nor would a splint be capable of attaining anything like the accuracy and comfort of the mere sling.

In the progress to recovery the arm at first continues disabled, and when freed from the sling tends to drop helplessly unless supported by the other limb or by another person. By degrees, however, the elbow can be held unsupported at the angle at which it has been slung, and eventually it can be flexed to less than a right angle. This is a test of approaching fitness for use.

Arthritis.—An ordinary sprain may develop into a subacute or chronic arthritis, especially in tubercular persons, if left to itself, or to the comparatively perfunctory assistance of fomentations, without mechanical help. Such arthritis may recover completely after due employment of rest in the slung flexed position; but in tubercle a pulpy condition of the capsule may result, with or without masses of granulations or abscess. A condition of "white swelling" of the elbow, with emaciation of the limb above and below, is typical of the advanced tubercular change, and, save in young children, there is no advantageous treatment for this, short of excision. A linear incision behind the joint, with dissection of the soft parts of the bones right and left, care being taken to keep close to the inner condyle, and to lift off the ulnar nerve intact with the other soft parts after separation of the ligaments, leads to exposure of the articular ends of the bones, which can now be sawn off beyond the cartilages. All tubercular soft parts should be carefully dissected away, or scraped with a sharp spoon, whichever more effectually answers the purpose at each locality. The term "arthrectomy" is sometimes applied to this part of the process; but the object desired is not necessarily removal of all the articular structures so much as the removal of all tissues visibly affected by the tubercular process. Caseous and granulation masses can be easily scraped away with the sharp spoon, but capsular and other fibrous tissues containing miliary tubercles require dissection. After arresting the hemorrhage and irrigating well with hot water, a few sutures are put in, and the limb placed in a proper position to receive the dressings. The writer always ties the wrist to the neck with a triangular bandage, the elbow, however, being flexed at a right angle, or even a smaller angle, in which position the part is enveloped in carbolized cyanide

gauze bandaged on. The effect of this position is to keep the limb in contact with the trunk. Wherever the body goes, the limb goes with it, and the comfort of the patient is promoted; or in other words, any discomfort attending the operation is reduced to a minimum. The writer is opposed to the use of a splint, or to laying the limb on a pillow "at an obtuse angle" after excision of the elbow. By slinging the wrist to the neck and the arm to the side, the pain and tenderness resulting from the wound are quickly got rid of, and the patient enabled to get up in a much shorter time than would otherwise be the case. The number of days or hours of confinement to bed varies with each case, but the writer has had patients able to be up and about the day after excision, though commonly a day or two more elapses before this event. There seems to be no need to trouble the patient to submit to "passive movement" of the elbow. It is sufficient at first to keep the wound at rest for healing purposes. But the position of the limb may be slightly changed after a week or two, alternating between a right angle and a more acute angle. In the opinion of the writer, it is quite time enough to accustom the elbow to slight changes of position when the healing is either completed or well advanced. Primary union may occur throughout if the circumstances are favorable, or, as a rule, in the greater part of the wound at least; but if not, each event will be dealt with as its circumstances require. After healing, fresh tubercle may develop here or there, and must be cut out if manifested. No case should be dismissed or lost sight of until completely healed; and any delay in the healing should be promptly treated by exploration, excision, scraping, or other antiseptic management.

Excision may be required for septic arthritis with sinuses following injury, for ankylosis, or for bad union or non-union of fractures at or near the elbow-joint. In some cases, especially where the surface is unbroken, opportunity arises for modifying the details of operation in the interest of the patient and to the mechanical advantage of the limb. Such a case occurred to the writer two years ago, in which a stiff extended elbow following a fracture of the outer condyle of the humerus into the joint was submitted to excision. The broken and ununited outer condyle was cut away with the knife, a thin slice only being removed from the head of the radius, so as to retain the orbicular ligament; the ulna, after removal of the olecranon, articulated opportunely with the broken outer side of the inner condyle, where it found good support; a strong and greatly thickened anterior ligament of the joint formed a bond of union which was gladly left alone, and the result was admirable mobility and strength of elbow after a very quick healing. The patient, a member of the civil service who had come home from India for treatment, went away again well able to ride and drive, to convey food to his mouth, and, in fact, to perform all necessary acts with a limb previously quite useless to him.

The object of surgery is to procure, if possible, a movable elbow; but too much should not be sacrificed to this end. Ankylosis at a right angle firm and strong, though usually a less desirable result than flexibility, is not necessarily to be despised, especially if the latter result be attended with very feeble power or, what is worse, an uncontrollable

"flail." The writer had once for a patient a joiner in whom the right elbow was firmly ankylosed at a right angle. The man could use a saw to his own satisfaction, and was quite content with the result—in fact, did not desire operation to procure mobility, which might easily have been attended with an enfeebled limb.

In **acute rheumatism** the elbows, when affected consecutively, as usually happens, are sufficiently protected in the ordinary attitude, as the arms lie on the bed and the forearms on the trunk. No interference is commonly required, and the inflammation generally disappears in a few days.

It will be noticed from what has been said that the mechanical treatment of the shoulder and elbow differs from that adopted in other joints. In the hip and knee, fixation and mechanical rest are obtained by splint, in a straight line. The same will be found to apply to the wrist. In the elbow, the limb is folded against the trunk and slung there in the flexed position of the joint. In the shoulder, the same attitude is used, and, in addition, the elbow is confined to the side, to prevent movement in the shoulder-joint.

DISEASES OF THE WRIST.

The wrist-joint is liable to inflammation owing to sprains, some of which are attended by swelling of the tendon-sheaths around the radius, more or less resembling cases of Colles' fracture, such as sometimes occur with very slight deformity.

Acute Rheumatism.—Inflammation of the wrist-joint is a common feature in acute rheumatism, and a source of great annoyance to the patient while it lasts. The usually transitory character of acute rheumatic arthritis, and the fact that the other joints are pretty well at rest as the patient lies in bed, have caused the affection of the wrists, during the few days that it lasts, to be not quite sufficiently noticed. The late Professor John Marshall drew the attention of the writer to the great comfort afforded to a member of his own family during rheumatic fever by promptly supporting the wrists in suitable splints as they became in turn affected—a practice that the writer has since repeatedly followed. The wrists are practically the only joints that require surgical treatment in acute rheumatism, and the contrast between the comfort thus attained and the painful helplessness of those left alone or submitted to loose applications of cotton-wool or the equally useless "fomentations" is too evident, when witnessed, to need more than mere mention.

Gonorrheal rheumatism of the wrist, like gonorrheal rheumatism of other joints, would appear to vary according to individual patients and experiences. In the experience of the writer, this affection, wherever found, has been usually mild and eminently amenable to mechanical treatment, except in a single case of unusual severity affecting the knees and ankles.

Tubercular inflammation of the wrist is an affection of very varying extent and severity. It often begins insidiously and quietly, producing so little inconvenience that serious destruction may occur before treatment, which might earlier have been curative, is ever asked

for. There is every degree between a slight arthritis and puffy excrescences of granulation and caseous tissue pouching out the joint at various points. When abscess forms and bursts spontaneously, a sinus is left. In middle life such a complication requires amputation of the forearm (Fig. 362). Abscess of the wrist-joint treated with an

FIG. 362.—Senile tubercle of the wrist treated by amputation. Puffy swelling and sinuses.

unbroken surface may be opened antiseptically, and may heal without any further suppuration at any age. In childhood and youth much may be done in the conservative management of tubercular inflammation of the wrist with splints and antiseptic incisions, with or without removal of bone where diseased.

The **mechanical treatment of the wrist** should be promptly and thoroughly attended to in all cases requiring it. Well-fitting splints of wood or sheet metal, hollowed for better adaptation to the limb, and suitably padded, reaching from the tips of the fingers to a point above the middle of the forearm, can be used for this purpose both effectually and neatly when not bulky. But a most convenient splint can be improvised out of folded newspaper in many layers, in the form of a trough wide enough to encircle the limb, enclosing the hand, wrist, and forearm, excluding the thumb, and bandaged firmly to the limb without any kind of padding. For severely sprained wrist the early application of such a splint is promptly attended by relief of all symptoms. Of course, to be efficient, the paper splint must be firm enough to rigidly prevent all movement of the wrist. The apparatus is left on till recovery is complete, and a single application may suffice in many instances. Perspiration escapes through the paper, which also lies smoothly and comfortably in contact with the skin. In the event of excoriation, or, in fact, at any time, the limb may be covered with a few layers of antiseptic gauze, which will suffice to preserve the surface of the skin and to render unnecessary the subsequent inspection of trifling breaches of surface. The same kind of splint will do for arthritis of the wrist unattended with sinus, abscess, or wound. In the event of abscess, the limb may be attached to a single splint of wood or sheet metal, after opening, scraping, washing, and dressing with cyanide gauze. The dressings may be so arranged as to be changed without disturbing the splint. After healing, a good

splint can be readily constructed by bandaging on a piece of sole-leather softened in water, in the form of a long gauntlet closely fitting the limb, its open side lying along its radial edge, leaving out the thumb. When the gauntlet is dry, it can be removed, trimmed with a knife, perforated with a few holes, and re-applied with a lace to hold it close. In certain tubercular cases perfect healing of the abscess may be thus attained by attention to antiseptic principles; but there may sometimes result inevitable stiffness, due to ankylosis in the wrist or radio-ulnar joint. Such cases present great varieties of condition and incident, but often will repay careful efforts to save them. There is no use temporizing, however, in cases of sinus in middle life. Prompt amputation is the most judicious treatment, as experience has amply shown. In children and young adults operations of a "cheese-paring" description may profitably be undertaken, inflammatory exudation, diseased bone, and other products of tubercular disease being excised by such means as the necessities of the case and the ingenuity of the surgeon suggest. Formal excision of the whole joint is seldom called for, even by the excellent method devised long ago by Professor Lister. The writer has succeeded admirably in a few cases by adopting the "partial" method of extirpating the local disease, subsequently preferred by Lister himself to his earlier practice.

CHAPTER XXII.

CONGENITAL DISLOCATION OF THE HIP; FLAT-FOOT; CLUB-FOOT.

CONGENITAL DISLOCATION OF THE HIP.

CONGENITAL dislocation of the hip is a dislocation of the head of the femur occurring in uterine life.

Etiology.—The etiology of this affection is not known. It would seem probable, however, that it is not a defect of development, like hare-lip, but, like congenital club-foot, a malposition of bones with the resulting structural changes of the soft parts. Girls are much more commonly subject to this affection than boys, for some unknown reason.

Pathological Anatomy.—Changes in the Capsule.—These are the most important pathological changes, and they are of gradual development. There is no rupture of the capsule, as in a traumatic dislocation, but it is altered by being stretched by the head of the bone, is forced upward, and is thickened and strengthened as the weight of the child increases. The shape of the capsule becomes altered from that of an irregular globe connecting the acetabulum and femur, and can be likened to a purse-bag glued to the bone, the lower portion covering the acetabulum, the free portion enclosing the femoral head, and the purse neck being the constricted part where the head of the femur left the acetabulum, stretching the adherent capsule with it. What may be termed the neck of the capsule becomes attached on its iliac surface to the ilium, and this attachment may be unusually firm; that covering the acetabulum becomes altered, and with the changes of the synovial membrane and stretched cotyloid ligament resembles firm fibrous tissue, filling as well as covering the socket, so that the cavity may be obliterated. Portions of the capsule may be much thickened.

Alterations in the Muscles.—The changes in the length and direction of muscles between the pelvis and femur vary according to the altered position of these bones. These alterations offer less resistance to reduction than those of the capsule, but they may be an important factor in causing a relapse and in resisting complete correction. The pelvifemoral muscles are especially to be considered—viz., the adductors, the tensor vaginæ femoris and the fascia lata, the reflected head of the rectus, and also the hamstring muscles, together with the psoas and iliacus. Those inserted at the great trochanter are not shortened, and may be lengthened.

Alterations in the Bones.—The acetabulum becomes shallow and triangular, and its hyaline cartilage is replaced by fibrous tissue, except at the rim. The formation of a new false joint with osseous socket is not seen in congenital dislocation in children, and is extremely rare in adults. Frequently the neck of the femur is twisted and its angle with the shaft diminished. The head may be small and pointed.

The **varieties** of dislocation are *backward*, *upward*, and *forward*, and are indicated in general by the position of the leg and the direction of the foot.

Diagnosis.—The diagnosis of this affection is not difficult in adult cases or in large children, as the characteristic peculiarities in gait and attitude are easily seen. In smaller children these affections must be eliminated: *coxa vara*, *distortion following infantile paralysis*, *separation of the epiphysis*, *deformity following early arthritis of infancy*, *traumatic dislocations*, and the *deformities of hip-disease*.

In all of these affections except coxa vara there should be a history of previous injury or illness, and in all except coxa vara and infantile

paralysis the freedom of motion of the femur seen in early congenital dislocation is not found. In coxa vara (rachitic distortions of neck of femur), unlike the conditions found in congenital dislocation, the femur rotates with the head in its normal socket and cannot be palpated. Coxa vara is rare before five years of age.

Congenital dislocation is characterized by marked lordosis, so as to be frequently mistaken for a spinal lesion. Whether the dislocation be unilateral or double, the gait is characteristic. In the former instance it resembles the gait on the free side of an organ-grinder carrying a barrel-organ; in the latter instance it is marked by a peculiar side-to-side movement. The gait is due to the muscular effort to relieve the ligaments of tension resulting from lack of bony support. Fluoroscopic examination, when feasible, is conclusive evidence in diagnosis.

Prognosis.—The disability caused by this affection in childhood is slight. The limp is noticeable, and in double congenital dislocation may be distressing. As the patient becomes older and the weight increases, some annoyance may be caused in adolescence, but the disability is ordinarily not great until middle life or old age. A single dislocation is less annoying. An increase of weight or overexertion may cause muscular pain and spasms, necessitating the temporary use of crutches, particularly in feeble subjects, and seriously limiting activity.

Treatment.—The problem to be solved in the treatment of congenital dislocations of the hip consists in replacing the head of the femur into the acetabulum, and keeping it there, so that the weight of the trunk is transmitted directly to the femur. The most important obstacle to reduction lies in the attachment of the capsule, displaced and thickened, to the ilium above and around the front of the acetabulum, and to the anterior surface of the femur, especially to the lesser trochanter. Of more or less importance are the shortened pelvifemoral muscles, as well as the shape of the head and the shallowness of the acetabulum.

The methods may be grouped as:

1. Reduction after incision.
2. Reduction by forceful manipulation.
3. Gradual reduction by mechanical appliances.

Reduction after Incision.—The first successful operative method was devised by Hoffa, the details of which have been much improved by Lorenz and by himself. The patient is to be placed upon the back with the limb abducted and rotated outward. The incision is made in a line drawn from in front of the anterior superior spine, obliquely downward and forward, crossing the femur a short distance below the top of the trochanter (Fig. 363). The incision should be along the outer edge of the tensor vaginæ femoris, between this and the anterior border of the gluteus medius. The incision should pass below the trochanter, and should cross the femur slightly above the level of the trochanter minor. The tensor vaginæ femoris is retracted, and the fascia lata divided by a straight incision, and, if necessary, by an additional cross incision. The gluteus is also retracted, and beneath the tensor muscle the rectus femoris will be found, with the reflected tendon passing out-

ward, to be inserted upon the ilium above the acetabulum. If the muscular tissues are well retracted, the capsular ligament will be uncovered and can be split. This should be done by an incision in the direction

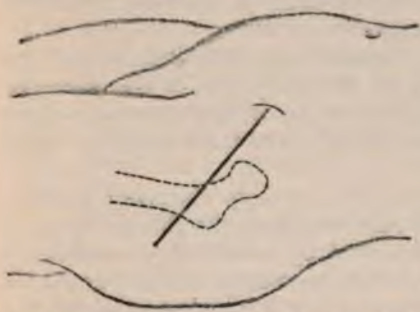


FIG. 363.—Line of skin-incision for operative reduction.

FIG. 364.—Operative reduction, second step.

of the original skin-incision, free enough to expose the whole head and neck as far as the trochanteric line. An assistant should then flex the thigh to a right angle with the trunk, and the attachments of the cap-

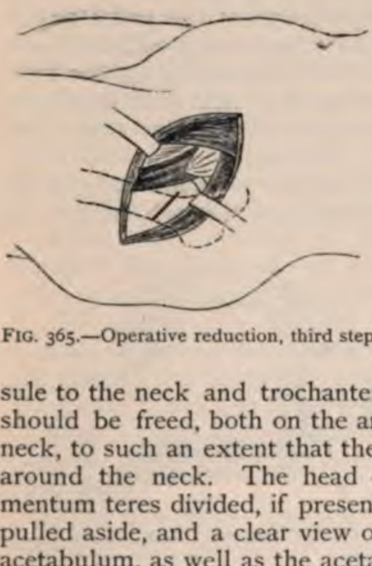


FIG. 365.—Operative reduction, third step.

FIG. 366.—Operative reduction, fourth step.

sule to the neck and trochanteric line, including the lesser trochanter, should be freed, both on the anterior and the posterior surface of the neck, to such an extent that the surgeon can pass his finger completely around the neck. The head can then be thrown out and the ligamentum teres divided, if present. The head of the femur can then be pulled aside, and a clear view of the capsule covering a portion of the acetabulum, as well as the acetabulum itself, can be had. A curet can then be introduced to deepen the acetabulum, if necessary. It is important that the bony edge overhanging the acetabulum should project sufficiently to furnish a firm socket after the head is reduced. It is sometimes difficult, if the tissues are imperfectly divided, to find the socket, for the reason that a portion of the capsule lies flat across the socket and is adherent to the edges, the surgeon feeling only the upper edge and a mass of connective tissue. This connective tissue must be divided in order to open the cavity.

It is best not to remove the cartilage from both the head of the femur and the acetabulum, in order to avoid subsequent ankylosis. It is important that all tense bands of the capsule should be divided, and that no portion of its capsule should get between the head of the femur and the acetabulum. The femur may be used as a lever to stretch certain undivided portions of the capsule.

After reduction, the redundant capsule can be stitched and the wound closed or drained according to the judgment of the surgeon. Results show that drainage is of especial importance on account of the depth of the cavity and the danger of infection from urine in small children.

The limb is maintained in a flexed and strongly abducted position by means of a plaster-of-Paris spica reaching from the thorax down to the foot. Access to the wound is obtained by means of a window cut in the plaster. The amount of abduction necessary at the outset will vary with the difficulty in keeping the bone in the socket; the limb is gradually adducted by means of subsequent bandages.

Although of comparatively recent date, it is thoroughly established by the results of Hoffa, Lorenz, and Delanglade that these cases can be cured by operation. In a series of 135 cases collected by Schanz, death occurred in 7 instances, but there were 109 excellent results.

Reduction by Forcible Manipulation.—The early attempts at forcible reposition under an anesthetic in congenital dislocation of the hip were not successful. Guided by his knowledge of the pathology of congenital dislocations, and profiting by his experience in reduction after incision, Lorenz has devised a so-called bloodless method for the treatment of these cases. This method has had sufficient trial to demonstrate its efficacy in certain adapted cases, and its greater safety than reduction after incision.

Reduction by forcible manipulation can be successful only if the head of the femur can be made to dilate and pass through the neck of

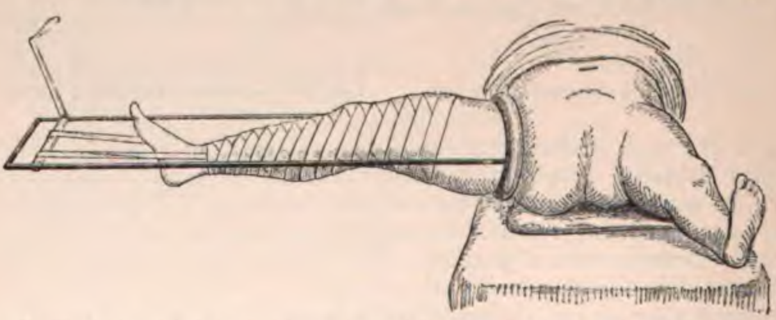


FIG. 367.—Method of forcible stretching under anesthesia, with forcible abduction and hyper-extension.

the capsule into the acetabulum, accompanied by the freeing and stretching of adherent and shortened portions of the capsule, as well as the lengthening of certain muscles. In children over two and under five years—in some instances between five and seven years—under an anesthetic, forcible reduction can be successfully used; but in some in-

stances it is by no means certain in bloodless reduction that a portion of the distorted capsule may not be folded in in front of the femur, making a relapse probable.

It is sometimes advisable as a preliminary step to stretch the muscles, and possibly the capsule. For this purpose the child is placed upon its back on a frame, and by means of weights and pulleys traction is exerted with the legs abducted more and more as the muscles yield. A counter-pull can be made by cross-straps pressing down upon the top of the trochanter. This can be done without causing the patient great discomfort, and a position of forced abduction nearly at right angles with the trunk of the limb can be gained in young children after a short time.

After this preliminary treatment the patient should be anesthetized, and then considerable force should be exerted by the hand, by means of apparatus with screw or windlass attachments, in such a direction as to overcome the adhesions, the shortened bands of capsule, and the contracted muscles.

The child is placed upon its back, the thigh much abducted, and traction exerted by means of a loop of yarn placed around the ankle or a padded anklet, and attached to a screw-force fastened to the end of the table, while at the same time counter-traction is maintained by means of a long sheet of folded cloth placed beneath the perineum on the unaffected side; or a windlass-traction attachment can be added to the well-known Thomas knee-splint. The force is transmitted to the leg through strips of adhesive plaster applied along and across the leg and thigh, firmly bandaged to the limb, and counter-resistance is met by the padded ring at the upper end of the splint pressing against the tuberosity of the ischium and ramus of the pubes. The limb is to be abducted as much as possible, and force slowly applied. This maneuver should be applied in various directions, stretching the adductor muscles, the flexors, the hamstrings and rectus femoris, and the capsule.

After a few minutes of forced mechanical hyperabduction with traction, the thigh should be alternately hyperextended, abducted, rotated, and circumducted in order to loosen all portions of the capsule. If the capsule can be thus sufficiently stretched, reduction can be affected by manipulation, and is indicated by an audible movement of the head of the femur into the capsule; otherwise an incision will be necessary in order to reduce the dislocation. Tendency to recurrence justifies further attempts at stretching, which may be aided by using the femur as a lever, provided the head can be engaged in the acetabular lip.

After bloodless reduction the limb should be strongly flexed and abducted, and kept in this position by means of a plaster-of-Paris spica. From time to time new bandages are applied until the leg assumes a normal position. A splint can be combined with massage for several months, and the protective appliances gradually removed.

After bloodless reduction the patient should be allowed to walk about on the abducted limb to exert pressure upon the acetabulum, to press through a fold of the capsule, if any remain.

Neo-arthrosis Operation.—Certain cases resist all attempts at reducing and maintaining the head of the femur in the acetabulum.

Hoffa has proposed an operation for these cases, on the ground that nature never forms a true new joint. In this operation the capsule is incised and the bone curetted and deepened to form a socket. The value of this method has not yet been thoroughly demonstrated.

Excision of the head of the femur does not seem to be a proper procedure in congenital dislocation.

Gradual Reduction by Mechanical Appliances.—Gradual reduction by mechanical appliances has not proved itself a reliable method of treatment; neither has the method of reduction by long-continued bed-traction.

TALIPES VALGUS.

The position of the normal foot, whether at rest or in action, is regulated by certain physiological conditions, which, when exaggerated or persistent, may give rise to the affection known as flat-foot. If the leg and foot hang loosely from the knee, the anterior border of the tibia can be projected in a relatively straight line to the space between the first and second toes. If the individual bears his weight upon the foot, this line forms an obtuse angle near the internal malleolus, pointing inward.

This anatomical change consists of a twist of the foot at the mediotarsal articulation, and also a sagging downward (or plantar flexion) of the head of the astragalus and the os calcis. This condition is exaggerated when the weight is borne on one foot alone, as demonstrated by foot-prints on smoked paper. The bones of the foot are arranged so as to form a transverse and two longitudinal arches sustained by ligaments when the foot is at rest, and supported, in addition, by muscles when in action. The addition of weight causes a slight lengthening and widening of the foot, of little importance compared with twist at the mediotarsal articulation. The important changes take place in the internal longitudinal arch.

The checks to the mediotarsal twist are largely the tibialis anticus and posticus muscles, but also the plantar fascia and plantar muscles, as well as the flexors of the toes, the various ligamentous bands which pass from the os calcis to the astragalus, the scaphoid and cuneiform bones on the sole of the foot, and the strong deltoid ligament. Within certain limits the amount of change varies according to the weight of the individual in relation to the strength of his muscles and ligaments. Deformity alone is no sign of suffering, as proved by athletes accustomed to bear great weights; but subjective symptoms arise when the muscles weaken, thereby causing the ligaments to stretch. Permanent distortion follows when the ligaments are lengthened, and in extreme cases the relative position and shape of the tarsal bones become altered so that complete inversion is no longer possible.

Etiology.—Anything which weakens the muscles and ligaments of the foot or disproportionately increases the weight to be overcome predisposes to the development of flat-foot. Furthermore, imperfect shoeing puts the foot at a mechanical disadvantage. The commonest faults of shoeing are pointed toes, high heels, short shoes, or shoes arranged so that the toes are crowded.

Symptoms and Diagnosis.—Flat-foot gives rise to but few symp-

toms beyond the deformity, the peculiarity of gait, and fatigue and pain in locomotion; but this chronic condition is interrupted at times by a muscular or ligamentous strain which causes an exaggeration of the peculiarity in gait, and may give rise to a limp, pain and a puffiness of the dorsum of the foot, and tonic spasms of the extensor muscles of the foot. The deformity of well-marked cases is characteristic. The sinking of the foot shows that the inner arch is lower than normal, and the lack of elasticity in gait is easily recognized, as well as abnormal eversion.

More care is needed to recognize the pathological flat-foot in children or in the lighter stages in adults. An impression of the sole-pressure on paper blackened by camphor-soot, first with but little weight, then with the whole weight of the body, is of value to indicate the area of maximum contact. The diminishing extent of the hollow under the inner arch is indicative of the flatness of the foot.

Treatment.—The treatment of these cases necessarily varies according to their severity, and for descriptive purposes we will consider these stages: 1. Light cases in growing children; 2. Severe cases in growing children; 3. Light cases in adults; 4. Severe resistant cases in adults.

In the light cases in children it is extremely important that proper shoes are furnished. The best covering for the foot is necessarily a shoe which constricts as little as possible. It is essential that the shoes be not too short, the toes broad, heels low; the instep should fit snugly, so as to prevent crowding of the toes. The soles of the shoes should be shaped so that the toes are not crowded or forced outward. Short stockings are injurious. Gymnastic exercises as mentioned for adults may be of value.

In the severer cases mechanical support for the arch of the foot may be necessary. In-soles with a stiffened or padded arch of saddler's felt will be sufficient in the lighter cases, with or without the raising of the inner edge of the sole and heel from $\frac{1}{4}$ to $\frac{1}{2}$ inch, for the purpose of throwing the weight more upon the outer side.

In light cases in adults supports to the arch are more necessary than in children, on account of the increased weight and strain. Suitable shoes should be ordered, and gymnastic exercises prescribed in order to develop the muscles which support the arch. The simple exercise of rising upon the toes a specified number of times, walking with heels raised, bending the knees and lowering the trunk with the heels raised, if thoroughly carried out, will be of service. The patient should walk with the toes straight ahead, and avoid a position with the foot everted.

The object of a support to the arch is partly to sustain a portion of the weight, but more particularly to maintain a proper position of the bones of the foot. The most readily made form of support is a strengthened leather inner sole.

This can be furnished by soaking a thin piece of ox-hide of the requisite size, containing but little oil, and applying it to the foot in the proper position, or, better, to a cast of the foot. When thoroughly dry and stiff the concavity of the inner arch is filled with layers of leather or made more resistant with strips of steel. This is to be

worn in the shoe, and will be comfortable if it is indicated and has been properly fitted.

In most instances needing support metal plates are the most serviceable, and the most efficient are those recommended by Whitman (Fig. 368). In this plate all injurious pressure is avoided, and it acts constantly to throw the weight toward the outer arch. The plate is worn inside the shoe, which should be of an approved pattern.

FIG. 368.—Whitman's brace for flat-foot.

This plate should be made from a plaster model of the foot in the proper position—*i. e.*, turned slightly inward. The plate should not be so long as to reach the heads of the metatarsal bones or the tubercles of the os calcis, but it should support the under surface of the scaphoid and the head of the astragalus. The metal should be strong enough not to yield under pressure.

In the severer cases, accompanied by muscular spasm and overstretched ligaments in the fixed eversion of the foot, it is necessary to fix the foot in as correct a position as possible by means of plaster bandages successively applied to the foot, using in some instances force under an anesthetic.

The treatment as mentioned above can be employed as soon as the patient's feet have sufficiently recovered. In certain severe cases with marked deformity of bone, a wedge-shaped portion can with benefit be removed from the neck of the astragalus or scaphoid, and then the foot inverted and fixed by means of a plaster bandage, with the ordinary treatment for flat-foot for the stage of convalescence.

The prognosis of the treatment of flat-foot is satisfactory.

CLUB-FOOT, OR TALIPES EQUINOVARUS.

Club-foot consists of a dislocation at the mediotarsal articulation, with resulting changes in soft tissues (skin, muscles, tendons, fasciæ) and bones or cartilages. The anterior part of the foot is inverted and twisted, and the heel elevated so that the patient walks on the outside and, in extreme cases, on the dorsum of the foot. The soft tissues especially involved are the abductor pollicis muscle, the tibialis anticus and posticus, plantar fascia, plantar and astragaloscaphoid ligaments, and tendo Achillis. The bony deformity of importance consists of an

inward rotation of the scaphoid and cuboid bones around the anterior surfaces of the astragalus and os calcis respectively, with occasional deformity of the astragalus and os calcis. Secondary changes may be the result of pressure or locomotion.

Club-foot may be congenital or acquired. The cause of the congenital variety is still a matter of theory; the acquired variety is almost always secondary to infantile paralysis, and it will not be further considered here. In congenital club-foot the muscles may atrophy from disuse, but are never paralyzed.

Symptoms and Diagnosis.—These patients suffer considerable inconvenience in walking, and the gait is unsightly and characteristic when the deformity is double, in that one foot is lifted over the other in a peculiar manner. Bursæ and callosities frequently develop, and they may be the seat of inflammatory processes. The position of the foot and the shortened ligaments are characteristic. By manipulation it may be possible to reduce the deformity more or less, but it will recur at once. The deformity increases as the patient walks upon the distorted foot.

Prognosis.—The deformity usually persists or increases if untreated, and shows no tendency to correct itself. Early cases are easier to correct than late ones. All cases are amenable to correction, and the deformity will not recur if complete correction or overcorrection has been secured for a sufficiently long period to enable the parts to have adjusted themselves.

Treatment.—The treatment will vary according to the age and condition of the deformity, and should be begun as soon as the nutrition of the child is such that treatment can be continued without interruption. Methods should be tried in the order of their simplicity, as a general rule. Our aim should be to overcorrect the deformity, and retain the foot in the corrected position until all parts become adjusted, and there is no tendency to recurrence when the foot is at rest and influenced only by gravity, and particularly when in walking it does not tend to assume its former distorted position.

All treatment is mechanical, with or without some surgical interference, but electricity and massage may be of value during convalescence.

Infantile Cases.—Here the foot is pliable, and the chief obstacles to correction are the shortened muscles and ligaments. Gradual correction by means of manual force and repeated plaster bandages can be employed, although often tedious.

The deformity is corrected in this order: Inversion at the ankle-joint, inversion at the mediotarsal joint (varus), and finally the plantar flexion (equinus). Plaster bandages are applied over a limb well protected with cotton, every two to four weeks, extending from the toes to the thigh, with the knee slightly bent in order to retain the plaster without slipping. In correcting the deformity care must be exercised that the cuboid is forced outward as well as the scaphoid, and that the heads of the os calcis and astragalus are forced inward; otherwise the correction is only apparent, and will not be permanent.

Sooner or later, according to the condition of the foot and the circumstances of the case, tenotomy is resorted to in order to free what-

ever bands may be necessary, particularly the tendo Achillis. After the operation the foot is retained ten days to two weeks in a plaster-of-Paris bandage, and then a varus shoe is fitted to the foot. The inside varus shoe devised by C. F. Taylor answers the purpose more thoroughly than other mechanical appliances, but it needs to be modified to each case and requires careful attention. Straps and buckles will answer in careful hands, but in order to prevent slipping when first applied, the foot may be held firmly to the padded foot-plate by

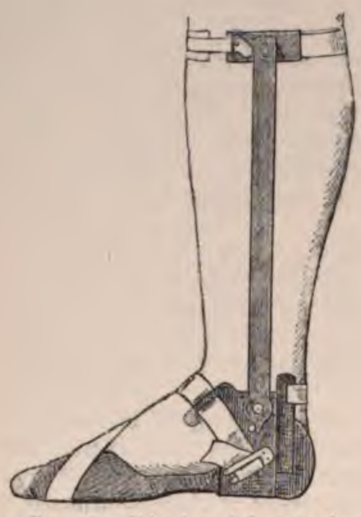


FIG. 369.—Side view of the retention apparatus applied inside of the leg.

FIG. 370.—Side view of the retention appliance: outside view, showing the leather side-piece, with metal ring through which the strap passes, exerting side-pressure upon the os calcis.

means of a plaster or silicate bandage; or in less experienced hands plaster bandages may be employed for a long period. The splint must be so arranged as to allow motion of the foot except inversion and plantar flexion beyond a right angle, and care must be taken that the external pressure is on the head of the os calcis, and not on the cuboid bone. The splint can be worn inside of a shoe, laced to the toe, and should be worn for a period sufficiently long to ensure moulding of the bones and tissues into a normal shape.

A subsequent operation is necessary if any fibers remain undivided, and in case of imperfect correction. Before the child is three years of age all deformity should be corrected.

Older Cases (**three to six years**).—In these cases the judgment of the surgeon must be exercised to a greater extent. Immediate over-correction is called for by both manual and operative measures, becoming more and more radical until the desired end is reached. In mild cases tenotomy of the tibiales, the plantar fascia, and tendo Achillis, and forcible correction by means of the hand or a wrench, will suffice; but if this fails, an open incision according to the method recommended by Phelps must be made on the inner side of the foot, and all resistant

structures divided. These procedures will correct most cases, and the retention treatment by means of plaster-of-Paris bandages and the varus shoe is the same as for the infantile variety.

When extensive alteration in the neck of the astragalus or the os calcis exists, an osteotomy of the neck of one or both of these bones is advisable, even in young children, and the results are far more satisfactory than those following excision of the astragalus or exsection of a portion of the tarsus—procedures involving unnecessary sacrifice of bone. In brief, the operation is as follows:

All internal bands having been previously divided, a curved incision is made, starting from the external malleolus, curving over the head of

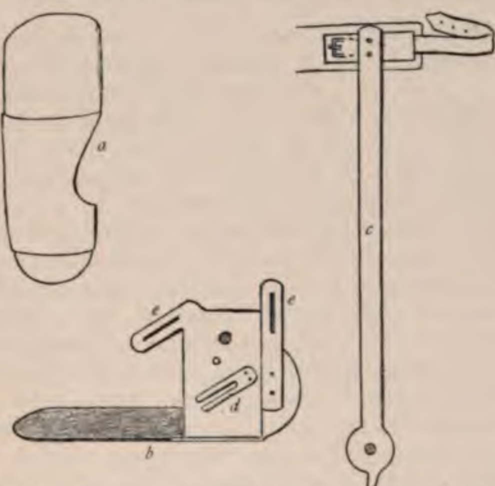


FIG. 371.—*a*, Sole-plate of retention-shoe; *b*, side view of sole-plate of retention-shoe, with securing clasp (*d*) and metal loops (*e*, *e*) for steadying straps; *c*, upright.

the os calcis and then down to the sole of the foot, and the flap reflected downward. The peronei tendons are turned aside or severed (to be sutured later), and on exposure of the neck of the os calcis it is chiselled through and a wedge-shaped piece of bone removed. The articular surface is not to be disturbed. This allows the cuboid bone to be forced out and up, and the foot to be corrected. In addition, in some cases the neck of the astragalus is to be divided by a linear or wedge-shaped osteotomy, if necessary. Perfect asepsis is demanded. When a good position is assured it is maintained by means of a plaster bandage. The after-treatment consists of a properly fitted varus shoe, with counterpressure over the heads of the astragalus and os calcis, and not on the cuboid bone, to be worn inside of the shoe for at least six months.

Adult Cases.—The ordinary measures are of no avail in these cases, on account of bony deformity and the presence of firm ligamentous bands. Radical treatment should be attempted at once, and the most favorable results are obtained after osteotomy of the astragalus and os calcis, as just described, though the removal of a large wedge of bone is needed. Convalescence is more rapid in these cases,

and the apparatus-wearing period shorter, for the weight and intelligence of the individual in using the foot are of much service.

In general, convalescent treatment may be summarized thus: In infantile cases, after complete correction, retention apparatus night and day for six months, walking appliance one to two years longer.

In children under five years, same precautions, except that walking appliances are needed longer.

In adults, following tenotomy, walking appliances about one year. After osteotomy, the same for about six months.

CHAPTER XXIII.

SURGERY OF THE MUSCLES, TENDONS, AND BURSAE.

INJURIES OF MUSCLES AND TENDONS.

THE most superficial muscles and tendons are naturally the most liable to injury, the principal injuries to which they are subject being contusions, sprains, rupture, wounds, etc.

Contusions of Muscles.—Contusions of muscles are of frequent occurrence, and are usually caused by blows or falls. A contusion may exist in any degree of severity, from a simple injury of a few muscular fibers to an extensive destruction of muscular tissue. On account of the hemorrhage which invariably takes place in all contusions, more or less blood accumulates at the seat of injury—so much, indeed, in some cases, as to form a distinct hematoma. Although contusions of muscles are generally simple, they frequently accompany severer injuries, such as fractures, dislocations, etc.

Signs.—The injury is recognized by pain and tenderness over the affected area, with some loss of power in the part. Passive motion usually causes considerable pain. Ecchymosis and swelling are quite certain to be evident sooner or later. Before making a diagnosis of simple contusion, it is well to exclude by careful examination the more serious conditions, such as fracture, dislocation, etc., which it may accompany.

Prognosis.—The outlook is favorable in most cases for a return to healthy conditions. The extravasated blood and the débris of muscular tissue are absorbed, and connective tissue replaces them. In some cases atrophy of the muscular fibers takes place, resulting in loss of power sometimes so persistent as to suggest the possibility of injury to the nerve. Occasionally suppuration occurs.

Treatment.—The object of treatment is to arrest bleeding, to cause absorption of extravasated products, and to prevent suppuration. The principal means at our disposal are (1) rest, (2) elevation of the part, (3) compression, and (4) cold. Where the injury is slight, all that may be necessary is to put the part at rest, to support and immobilize it by bandages, etc.; but in the more serious cases the patient should be put to bed, and the affected part raised, if possible, so as to limit the amount of blood going to it. Cold (best applied in the form of ice-bags) may be used with advantage, especially when there is a tendency to hematoma. As the latter, when it is large, requires a long time for absorption, and furnishes a good opportunity for suppuration, it is occasionally advisable in the early stages to wash out the clot through a small incision. If suppuration takes place, early incision and thorough cleansing of the cavity are called for.

Sprains and Strains of Muscles and Tendons.—A sprain or strain of a muscle or tendon usually means the injury resulting from (1) an undue stretching from external violence, (2) sudden or violent contraction of the muscle, or (3) the continued overuse of one muscle or group of muscles.

Signs.—The affected muscle is usually painful and tender, and has lost a certain amount of its power. The pain and tenderness may be felt at any part of the muscle itself, or at the point of insertion of the tendon. Occasionally there is some ecchymosis.

Prognosis.—The condition is not usually a serious one, although in certain cases, in spite of the most approved treatment, some of the symptoms persist indefinitely. This is particularly true in sprains of the small of the back, the shoulder, hip, etc.

Treatment.—The special objects of treatment are to relieve pain and to restore the lost tone of the muscle. These are effected by resting the part and by carefully graduated compression. Massage is frequently useful, and sometimes, especially in the later stages, counter-irritation may be of advantage. Occasionally one sees cases of what are called "chronic sprains" or "strains," caused by the overuse of certain muscles, where the pain is principally at the origin or insertion of the muscles. Tenderness and stiffness are prominent symptoms. Examples of this are seen in the so-called base-ball pitchers' arm, tennis-elbow, etc. Persistent overuse of a muscle may give rise to a local periostitis at one of the points of attachment of the muscle, possibly resulting in necrosis (see cases recorded by Paget). Occasionally, as a result of these repeated strains, an ossification of muscle or tendon may take place at one of its points of attachment to the bone. The best instance of this is what is known as "riders' bone," which is a core of ossification within the tendon of the adductor longus, in men who are much on horseback.

Rupture of Muscles and Tendons.—Muscles and tendons are ruptured not infrequently as a result of some sudden and violent muscular contraction. This may take place in persons in the vigor of youth, but is more apt to occur in those of middle or advanced age, whose tissues have lost some of their elasticity, and especially in cases where the muscles have become degenerated by long and exhausting illness. The rupture of muscle may be partial or complete. The investing fascia of the muscle alone may be ruptured, allowing protrusion of the muscular tissue through the gap thus made (hernia of muscle), or the muscle itself may be partly torn through, or may be ruptured through its entire thickness, in which case there is a pronounced retraction of both ends. When a tendon ruptures, the contraction of its muscle-belly draws the fragment attached to it away from the other fragment. In any of these injuries more or less blood escapes into the tissues.

Signs.—During effort a sudden sharp pain is felt, followed at once by a feeling of helplessness in the part. The site of the injury is tender, and in most cases a gap can be seen or felt there. Sooner or later there will probably be some ecchymosis and swelling.

Treatment.—The principal object of treatment being to restore as nearly as possible the continuity of the ruptured structure, the part

should usually be placed at rest, by bandages, splints, etc., in such position as to relax the muscle most thoroughly and approximate the torn ends, and ice-bags should be applied. In suitable cases the torn muscle or tendon may be united by suture (preferably chromicized catgut), after which the part should be placed in the position of greatest relaxation for the muscle. In either case massage or electricity will usually be found of benefit in the later stages. Suture of muscle should never be tried if there is reason to suppose that the muscular tissue is degenerated. Primary suture of ruptured tendons is generally, and even secondary suture is often, successful.

Rupture of the plantaris is not uncommon. This muscle arises from the back of the femur just above the external condyle, and is inserted into the posterior surface of the os calcis. It is analogous to the palmaris longus, and, like that muscle, is occasionally absent. The muscular belly (about 3 or 4 inches long) is inserted into a long, narrow tendon. During a sudden motion, as in lawn-tennis, wrestling, boxing, etc., a sharp stinging pain is felt in the calf, like a whip-stroke. The part is tender, and soon becomes swollen, and probably ecchymosed. The patient should be put to bed and the leg immobilized on a ham-splint. In a few days he may get up and walk (at first with crutches or cane), keeping the heel to the ground. The injury is of no great consequence, and the patient will probably recover entirely in a couple of weeks or so.

Rupture of the Biceps of the Arm.—Though the muscle itself is rarely ruptured, its tendons are more frequently the seat of this injury

FIG. 372.—Rupture of the tendon of the long head of the biceps.

than is generally supposed. The long tendon which arises from the upper border of the glenoid fossa is most frequently ruptured of all the parts of this muscle, and this is especially liable to occur where the tendon has been worn to a thin ribbon, as in cases of rheumatoid arthritis of the shoulder-joint. It generally gives way at or close to its

origin, and slides down the bicipital groove, where in time it acquires a new attachment. During unusual exertion in lifting, a snap is felt by the patient, as of something giving way, and the arm falls helpless. The arm cannot be flexed voluntarily at the elbow, the attempt to do so causing pain referred to the shoulder and along the bicipital groove. This region is very tender and may be ecchymosed. The deformity is characteristic. The muscular belly of the biceps is unduly prominent, but is soft and flabby to the touch. The outer head of the muscle has collapsed downward, and just below the lower margin of the deltoid there is an unnatural depression (Fig. 372) in which, by deep pressure, the lower end of the prolapsed tendon can be felt.

The arm should be bandaged from the fingers to the shoulder and placed in a sling.

When the tendon of insertion is ruptured, it is most frequently torn away from its insertion into the tubercle of the radius. The injury may

FIG. 373.—Rupture of the tendon of insertion of the biceps (author's case).

be recognized by the history of the case and by the existence of a transverse gap across the front of the arm just above the elbow (Fig. 373). In such a case an attempt should be made by open incision to stitch the two ends together. The writer was once obliged to sew the tendon to the brachialis anticus beneath it, as the entire tendon had been torn away from the bone. The arm should be kept in a position of acute flexion, with supinated forearm, for three or four weeks, after which passive motion and massage may be started. The short head of the biceps is rarely ruptured, and still more rarely the belly of the muscle itself.

Rupture of the Tendon of the Quadriceps Extensor, etc.—Rupture of the tendon of the quadriceps just above the patella is caused by

the same forces that cause a fracture of the patella itself. There is a violent action of the muscle when the knee is slightly bent. The patient experiences a sudden pain, and he cannot stand or extend his thigh. There is a marked transverse gap across the front of thigh just above the patella, made more evident by the bunch of contracted muscle above it (Fig. 374). An attempt should be made to stitch together the torn ends of the tendon, as otherwise the disability is pretty sure to be total and permanent. After this the leg should be kept in position of extension for several weeks. Rupture of the *ligamentum patellæ* is occasionally met with. If it is found possible to do so, it should always be united by sutures. The *tendo Achillis* may be ruptured—an injury easily recognized. The torn ends should be stitched together, the knee strongly flexed and the foot extended, and this position maintained for three or four weeks. The *sternomastoid* of the child has been ruptured, partially or completely,

FIG. 374.—Rupture of the tendon of the quadriceps extensor.

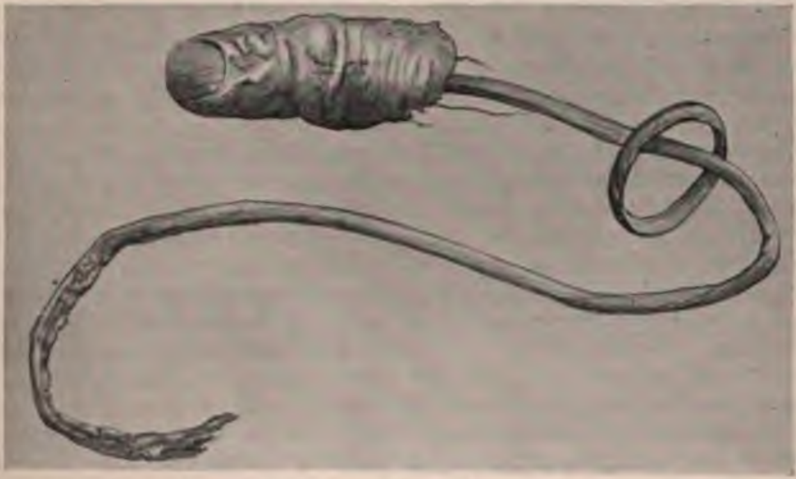


FIG. 375.—Drawing from a specimen in the Warren Museum at the Harvard Medical School, Boston. A ring which the person wore on the little finger caught on a nail, and the end of the finger was torn off, bringing with it the flexor tendon.

by the use of instruments in difficult labors; the *rectus abdominis* in parturition and in tetanus; some of the *flexors of the forearm* in athletic sports; and the *adductors* of the thigh in spasmodic efforts, during

riding, to retain the seat in the saddle. The *triceps* of the arm and the *psoas* have also been ruptured.

Thus far, mention has been made of rupture by voluntary effort only; but muscles and tendons may be extensively torn in dislocations and in fractures by splinters of bone. Tendons may be pulled away from their muscles, as is occasionally seen when a finger is torn off by machinery, bringing with it one or more of the long tendons which are inserted into it (Fig. 375).

The flat *abdominal muscles* may be ruptured by extreme violence, even when the skin is not torn through, as when a wagon-pole is driven with great force into the abdomen. In case the person survives the injury, ventral hernia is the probable result.

Dislocation of Tendons.—A dislocation of a tendon is an uncommon accident. It occurs perhaps most frequently to the *peroneal tendons*, which may become dislocated from their groove behind the external malleolus. This dislocation is easy to reduce by extending the foot and manipulating the relaxed tendons back into place. Once reduced, however, they have a constant tendency to spring out again, and an operation may be called for to narrow the enlarged sheath or to deepen the bony groove. A few cases have been reported of dislocation of the *tendon of the long head of the biceps*, though it would hardly seem as if this injury were an anatomical possibility. During a sudden and violent twist of the arm the tendon slips out of its groove to the inner side, causing a sickening pain with immediate loss of power. If the muscle is relaxed and the part manipulated, the tendon springs back into place and full power is at once regained. Dislocations have also been reported of the *tendons of the tibialis posticus, sartorius, extensors of the fingers*, etc.

Wounds of Muscles.—Muscles are frequently wounded accidentally or intentionally (as in assaults, operations, etc.). Such wounds may be punctured, incised, contused, or lacerated. The injured muscle can usually be seen in the open wound.

Treatment.—The entire wound and the skin for a considerable area about it should be thoroughly cleansed and rendered aseptic. The wound should then be inspected, any foreign bodies which may have lodged there removed, and shreds of tissue which are only partially attached should be trimmed off. If the muscular fibers have drawn away from one another, leaving a gap, an attempt may be made to unite them by animal suture (preferably catgut), and the skin stitched together over them. Wounds which are too small to be properly inspected may be cleansed by irrigation and the curet, or may be freely laid open and treated on the general plan outlined above.

Wounds of Tendons.—As is the case in muscles, the tendons that are most often wounded lie nearest to the surface, and it is for this reason that the tendons about the wrist and hand, ankle and foot, most frequently suffer in this way. A wound in a tendon is usually incised or lacerated.

Diagnosis.—In case a wound is near a tendon, the diagnosis of severed tendon is highly probable when there is complete loss of power in the part to which the tendon goes; but a positive diagnosis can hardly be made unless at least one end of the divided tendon is seen.

Treatment.—When a tendon is completely divided, the only rational treatment is to find the ends, bring them together, and stitch them. It is highly important that as nearly as possible the normal length of the tendon and its original mobility should be preserved. An anesthetic should be given to the patient and a tourniquet applied, after which the wound should be thoroughly cleansed and examined. If both ends of the tendon are not at once visible, the limb should be placed in such a position as to relax the muscle to which the tendon belongs. It is, as a rule, easy to find the distal end of the tendon, but the proximal end is usually pulled away from the wound by its muscle. This end is usually found by enlarging the wound in the direction in which the tendon probably lies; but this method has the objection that the scar resulting from such a cut would presumably increase the liability of adhesions, and thus limit the subsequent mobility of the tendon. Several methods have therefore been devised for finding the proximal end. Perhaps the best of them is division of the skin and underlying tissue at some distance from the wound, in the presumed direction of the tendon. After the tendon has been found and identified the sheath is cautiously opened and the end of the tendon drawn out through it and fastened to the eye of a probe which has been passed from the original wound. This end can then be pulled into the original wound and stitched to the distal end with silk or chromicized catgut. A stay-suture may be used if the tension is considerable (Figs. 376, 377).

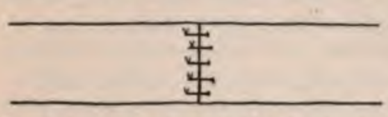


FIG. 376.—Simple suture of divided tendon.

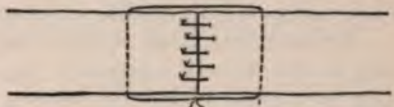


FIG. 377.—Suture of the tendon with reinforcement.

The skin should then be united with sutures, and the part kept in such a position as to secure the greatest amount of relaxation for the muscle. Drainage is usually not necessary. When there is a gap between the two ends of the tendon from loss of substance, a bridge between them may be made in the manner shown in the accompanying illustration (Fig. 378).

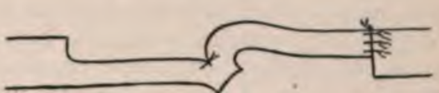


FIG. 378.—Method of lengthening divided tendon.

Tendons from animals have been grafted into such gaps with success, and Glück was equally fortunate with strands of fine catgut. In three or four weeks after the operation massage and passive motion may be begun, and should be faithfully carried on for months. The functional results obtained in such cases are usually very satisfactory, occasionally even when suppuration has occurred. There is often great difficulty, when several tendons are divided, in properly matching them; in fact, in some cases of wounds across the wrist it is well-nigh impossible to do so. Secondary suture of tendons has also been attended with considerable success. In such cases there is always a gap to be bridged over, owing to the fact that there is usually a mass of cicatricial tissue to be removed before the ends of the tendon can be sutured.

DISEASES OF MUSCLES.

Inflammation of Muscle (Myositis).—This usually appears in a subacute or chronic form, and is due to injury, overwork, exposure to cold and wet, or rheumatism. It also may result from inflammation spreading from contiguous tissue. There is usually an exudation between the muscular fibers, which in the less severe forms is absorbed, but in the more persistent ones organizes and later contracts, thus causing real atrophy of the muscular fibers themselves. Occasionally the inflammation may advance to suppuration. In very rare instances ossification takes place in various muscles in the body (myositis ossificans). The cause and pathology of this disease are as yet unknown.

Symptoms.—Pain and stiffness are prominent symptoms. The pain is often severe, especially at night. The area over the affected muscle is extremely tender and often swollen. The pain, tenderness, and stiffness in the muscles of the back from which many individuals suffer are probably due in a certain proportion of cases to some form of myositis.

Treatment.—Rest is especially necessary in myositis, together with counterirritation (in the form of friction with liniments) or hot applications. The bowels should be kept open and a light diet prescribed. In case suppuration occurs, an incision should be made and the cavity washed out and drained. In rare cases myositis occurs in a very acute form, when it is generally progressive, and soon proves fatal.

Tubercular and Syphilitic Disease.—Muscles may occasionally be the seat of tubercular or syphilitic deposits, the former generally associated with tuberculosis in some adjacent bone or joint, and the latter usually appearing in the form of gummata. It has been stated that gummata are very frequently found in the sternomastoid muscle of children born with inherited syphilis; but these swellings are probably in a very large proportion of cases due to rupture of the muscle during instrumental delivery.

Hypertrophy of Muscle.—Hypertrophy of muscle is generally the result of unusual and persistent exercise. The limbs of athletes and hard-worked laborers present familiar examples of hypertrophy of voluntary muscles, while the hypertrophied heart and bladder are good instances of the same condition in involuntary muscles. The muscular coats of the appendix are usually found to be much thickened after attacks of inflammation, as a result of the ineffectual efforts on the part of that organ to expel its contents into the cecum.

Atrophy of Muscle.—Just as muscles may become hypertrophied by extreme use, so they may become atrophied by long disuse. This is a familiar sight in limbs which as the result of fracture, joint-disease, etc., have been kept at rest for a long time. The supply of blood which has been furnished to the muscle is insufficient for its nourishment, and the muscle wastes. Atrophy of muscles from diminished blood-supply may also result from any cause obstructing the flow of blood through the arteries, as ligature, thrombus, pressure from tumors, etc. All such cases are embraced under the term *simple atrophy*, and are usually not accompanied by any form of degeneration. The mus-

cle still reacts to electricity, though its size, strength, and tone are diminished. Such cases call for exercise, massage, electricity, etc.

Another form of atrophy, due generally to interference with the nerve-supply, and sometimes due to injury, is called *atrophy with degeneration*, because the muscular fibers have undergone some form of degeneration (fatty, waxy, granular, or vitreous). The function of the muscle is either partly or wholly lost, and the electrical reaction is greatly diminished or absent. This variety of muscular atrophy is an especially prominent feature in progressive muscular atrophy, infantile paralysis, and pseudo-hypertrophic paralysis.

Transplantation of Tendons.—The procedure by which the distal tendon of a healthy muscle is cut across and its proximal end is stitched firmly into the tendon of a paralyzed muscle is an operation which belongs more properly under Orthopedic Surgery than here, yet a few words concerning it may not be out of place in this connection.

The operation, which is a comparatively new one, has thus far been confined to cases of paralysis of certain muscles of the lower extremity, when deformity has resulted on account of the active muscles, whose antagonists are paralyzed, pulling the foot or leg into a position of uselessness or deformity. Under such circumstances it is desirable not only to correct the deformity, but, by counterbalancing the traction of the active muscles whose antagonists are paralyzed, to prevent a recurrence of the deformity; and it is precisely this effect which the transplantation of tendons, as here described, is designed to accomplish.

The healthy peroneus longus has been transplanted into the tendo Achillis, into the tendon of the tibialis posticus, and into that of the tibialis anticus. The tibialis anticus tendon has been inserted into the tendon of the extensor proprius pollicis; and the paralyzed rectus femoris has been reinforced by the implantation of the sartorius.

The results of cases thus far recorded have been sufficiently satisfactory to justify the operation.

Functional Disorders.—A muscle may temporarily lose its power as a result of overwork, strain, exposure to cold, etc. It may or may not be subject to spasm also. Groups of muscles, especially those which combine to carry out the motions necessary for a certain action, may be similarly affected, the loss of power or the spasm being particularly marked when the attempt is made to carry out that action. A familiar instance of this is known as "writers' cramp."

Contractures of Muscle.—This refers especially to those cases of contracted muscles in which there is no relaxation, even when an anesthetic is given, and not to that class of reflex contractions accompanying fractures, inflamed joints, hysteria, etc. The simplest forms of contracture—such, for instance, as result from a part remaining a long time in one position—should be treated-with passive motion, massage, etc. But if this treatment fails, and also in the more serious forms of contracture where there is permanent contraction of the fibrous elements of the sheath and atrophy of the muscular fibers, the patient should be etherized, and an attempt made to overcome the contraction by force. This will be successful in all except the most

serious forms, where tenotomy will be found necessary. Tenotomy may be done by the subcutaneous or the open method, the latter having the advantage of enabling the operator to see what he is doing, and thus avoid damaging important parts. The tendon may be cut transversely, or, what is often better, may be split lengthwise and cut out at the two ends in opposite directions transversely or obliquely.

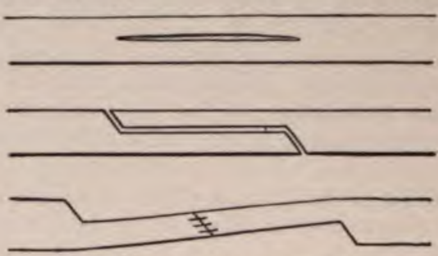


FIG. 379.—Method of lengthening a tendon.

The part should then be forced into the normal position, the two extremities of tendon united with catgut or silk, and the wound closed (Fig. 379). The result of tenotomy performed by either method is usually most satisfactory.

Tumors of Muscle.—Tumors of muscle, exclusive of those which affect the uterus, are rare. Most varieties of tumor have been found, however, sarcoma and its combinations being perhaps the most frequently met with. They should be dealt with in accordance with the general rules for the treatment of tumors.

DISEASES OF TENDONS, TENDON-SHEATHS, AND FASCIAE.

A tendon-sheath is a closed sac which partially or completely surrounds a tendon, its inner layer being adherent to it. Those tendons which possess sheaths are located chiefly about the wrist, hand, and ankle.

Inflammation of the Tendon-sheaths (Tenosynovitis).—Several varieties are met with: 1. Acute simple tenosynovitis; 2. Suppurative tenosynovitis; 3. Chronic tenosynovitis.

Acute simple tenosynovitis frequently follows overwork, sprains, and other injuries. This form of the disease is generally met with in one or more of the tendon-sheaths near the wrist, especially in those of the extensor tendon of the thumb or fingers, and occasionally in connection with the peroneal tendons or extensors of the foot. There is an elongated, irregular swelling over the region of the affected sheath, from effusion into the sheath, and the part is tender and painful, especially on movement. In the early stages a soft crepitus can usually be felt when the tendon moves to and fro in its sheath (tenosynovitis crepitans).

Treatment.—Gentle pressure should be applied by covering the part with a layer of contractile collodion or by sheet wadding, and immobilizing the part. Usually, under this treatment the inflammation subsides in a few days, and the exudation is absorbed. Occasionally, adhesions or chronic inflammation may result.

Suppurative tenosynovitis results from direct infection of the sheath with pus-producing organisms, or from suppurative inflammation in the neighboring structures. This condition is also occasionally met with in connection with gonorrhea or pyemia, either of these diseases appearing primarily in the sheath, or secondarily to some joint-affection. Acute suppuration of the tendon-sheaths on the front of the hand and wrist occurs so frequently in some forms of whitlow (the thecal variety) as to merit a special consideration.

Thecal whitlow (felon) usually follows some wound on the finger, but occasionally appears without apparent cause. The suppurative inflammation usually starts from the end of one of the fingers and spreads rapidly over the flexor surface of that finger. If this condition is neglected, sloughing of the tendon or necrosis of one or more of the phalanges may result, as well as invasion of some of the phalangeal or carpal joints, in which case the finger becomes distorted and useless. Septicemia and pyemia have been known to ensue. A special anatomical arrangement of the sheaths of the flexor tendons makes it possible for suppuration in the sheaths of the tendons of the thumb and little finger to travel up to the palm, and even under the annular ligament into the forearm, with amazing rapidity (Fig. 380). Whitlow, therefore, forming on either of these fingers is far more dangerous than on either the fore, middle, or ring fingers.

Symptoms.—Acute suppuration in tendon-sheaths extends rapidly throughout the entire length of the sheath, and is accompanied by the

FIG. 380.—Diagram showing arrangement of flexor sheaths on the front of the hand.

FIG. 381.—Diagram showing proper incisions into the palm.

usual symptoms characteristic of acute suppuration. In whitlow the pain is extreme and of the throbbing kind, increased almost beyond endurance when the hand hangs down. The finger appears red, shiny, swollen, and is exquisitely tender. Lymphangitis and brawny infiltration of the tissues of the forearm may follow as the inflammation

travels upward. In pyemia suppuration appears insidiously in one or more sheaths without causing special symptoms except swelling.

Treatment.—Before the presence of pus is evident, hot creolin baths and creolin poultices may be employed with advantage; but when suppuration has taken place, a free incision (Fig. 381) should be made at once, and the entire track of the abscess cleaned, washed out, and scrubbed with hydrogen peroxid. If immediate incision is made, it prevents the spreading of the suppurative process to other structures, and probably saves the tendon. Free drainage should always be used. The palmar incision of W. A. Brooks (see page 73) has much to recommend it.

Chronic tenosynovitis may be chronic from the beginning, or may result from repeated acute and subacute attacks, especially in individuals who have a tendency to tuberculosis. There are several varieties of the disease, though modern pathology considers a very large proportion, if not all, of them to be tuberculous. The sheath is distended with fluid, which may be serous, somewhat turbid, or gelatinous, and may contain numerous small bodies, the so-called "melon-seed bodies," which are made up of concentric layers of fibrinous material, and which float freely within the sac. The lining of the sac may be smooth or roughened with fibrinous deposit. In still another form of the disease, the so-called "fungous" variety, the sac is filled with granulations, which may burst beyond the limits of the distended sac and invade the neighboring structures. The sheaths most frequently affected are those on the front of the wrist (the so-called great carpal bursa), the back of the wrist, the dorsum of the foot, and behind the external malleolus (the sheaths of the peroneal tendons).

FIG. 382.—Chronic tenosynovitis of the flexor tendon-sheaths on the front of the wrist.

Signs.—The disease appears as a chronic elongated swelling over the tendon. There is little or no pain or tenderness, and the skin is usually not reddened. The swelling is soft and elastic, and gives an indistinct feeling of fluctuation. When the great palmar bursa is affected, there is a swelling in the palm and also one above the wrist, the two being separated by a constriction at the level of the annular ligament (Fig. 382). As the fluid is pressed from one swelling to the other, a peculiar soft crepitation may occasionally be felt, which is caused by the melon-seed bodies passing under the annular ligament. Some of the sheaths of the other flexor tendons of hand or fingers may be affected at the same time. In the fungous variety of the disease the skin may become involved and break down, resulting in ulcerations and sinuses.

Treatment.—Although most cases of chronic tenosynovitis are probably tubercular, and will resist all ordinary forms of treatment, it may be well in simple cases to try the effect of immobilization, firm

compression, counterirritation, etc., combined with tonics and good hygienic surroundings. If these fail after faithful trial, the entire sac with all its contents should be carefully removed by dissection, together with any tissue outside the sac which appears to be affected. The use of an Esmarch tourniquet will greatly simplify the operation. The functional result, especially when the disease is primary, is usually very satisfactory, and in most cases there is no recurrence of the disease.

Ganglion.—A ganglion, or "weeping-sinew," as it is sometimes called, is a round, firm swelling in connection with a tendon-sheath. It has thin walls and a synovial lining, and contains a thick gelatinous fluid. Its most common situation is on the dorsal aspect of the wrist, where it lies in intimate connection with the sheath of one of the extensor tendons of the fingers (Fig. 383). It is also occasionally seen in connection with the flexor tendons on the anterior surface of the wrist, or even in the palm. Its mode of formation is not entirely clear,

FIG. 383.—Ganglion on the back of the wrist.

though it is probably developed from a protrusion of a pouch of synovial membrane of the tendon-sheath through some aperture in its fibrous envelope. This pouch becomes larger and larger, possibly as the result of excessive secretion of synovial fluid from overuse of the tendon, sprain, etc. Apparently in most cases the neck of the sac becomes more and more constricted, and finally its lumen is obliterated, so that all connection with the cavity of the tendon-sheath is shut off.

Treatment.—A ganglion may be treated by subcutaneous rupture, subcutaneous incision, or by excision of the sac and its contents. It is usual, when the situation of the ganglion will allow it, to try these various expedients in the order here given. Thus, a ganglion on the back of the wrist is made prominent by strongly flexing the wrist, when the sac is ruptured by firm pressure with both thumbs, or by a quick blow with a heavy book. It is well after this to keep the hand and forearm confined to a splint for a few days, with firm pressure applied over the seat of the ganglion. Even after successful rupture, however, the sac may refill, and a different kind of treatment should be used. The skin may be pulled to one side over the swelling, and a tenotome passed quickly into the cavity of the sac. The inner lining of the sac is then scarified by the tip of the tenotome, or the entire sac-wall divided subcutaneously, after which the contents of the sac are squeezed out and the skin allowed to slide back to its proper place,

thus leaving a long oblique opening into the sac, which diminishes the danger of infection. The last resort in these cases is excision of the entire ganglion—an operation which, properly done, is invariably successful in preventing a return of the condition.

Dupuytren's Contraction of the Palmar Fascia.—This is a condition in the palm of the hand, which, from its appearance and from the fact that one or more fingers are permanently flexed, formerly gave rise to the impression that it was due to a contraction of the flexor muscles or tendons. Baron Dupuytren was the first to point out that the condition is entirely due to a contraction of the palmar fascia, and since that time the disease has always borne his name. The fascia in the palm opposite one or more of the fingers (the disease usually begins opposite the ring or little finger, and may spread to the others) is thickened and projects from the palm in the form of one or more rounded cords or bands to which the skin is quite firmly adherent, being disposed over it in many transverse folds and depressions. One finger only may be flexed, or several in different degrees. The flexion may be slight, or it may be so extreme that one or more fingers are brought into the palm (Fig. 384).

FIG. 384.—Dupuytren's contraction of the palmar fascia (after Reeves).

The condition is more frequent in men than in women, and is oftener found in the right than in the left hand, though occasionally in both. Though this contraction probably results from some form of chronic inflammation, its exact cause is not at all clear. In certain cases it seems to have been traced to some slight or repeated injury or to the continuous use of certain tools. It has also been attributed to rheumatism, though probably without sufficient reason.

Treatment.—Forcible extension does no good whatever. The deformity returns just as soon as the extension is discontinued. Operation is the only means by which a cure, or even improvement, can be expected; and even with operation a certain amount of recontraction may occur, especially if the wound fails to heal by primary union. The contracted bands may be divided by multiple subcutaneous incisions, or, what seems better, they may be dissected out freely through an open incision in the palm. A V-shaped incision, with apex toward the fingers, is strongly advised, as giving the operator, on lifting the flap, more room to dissect out all the contracted bands, and, by placing the skin-incision away from the tendon, to minimize subsequent recontraction after the wound has healed. The finger should be kept extended for two or three weeks after the operation, and later, massage should be used.

A slight degree of Dupuytren's contraction which shows no tendency to increase does not, as a rule, call for any operation whatever.

Hammer-toe.—This is a common deformity in which the tendons

and muscles take sufficient part to justify its consideration here. The deformity is most frequent in the second toe, though it may exist in any of the smaller toes. Both feet are often affected. The first phalanx is extended, the second strongly and rigidly flexed, and the terminal phalanx either in a straight line continuous with the second, or extended

FIG. 385.—Hammer-toe.

upon it (Fig. 385). A callus forms over the head of the first phalanx, and another on the tip of the toe, these representing the places subjected to the greatest friction when the foot is moved within the shoe. As might be expected, this condition makes walking difficult and painful. Though inheritance, rheumatism, and gout have often been considered responsible for this deformity, it is probable that the most frequent if not the sole cause is to be found in the wearing of shoes which are either too short (thus pressing the toes back) or too narrow at the tip (thus squeezing the toes together), or both. Assuming that hammer-toe is, as the writer believes it to be, invariably caused by defective footwear, its development may be explained as follows: An unusually long second toe is forced backward by a short shoe, and at the same time, on account of lateral crowding, is overridden by the great toe on one side and the third toe on the other. The tip of the second toe is never again able to return to its proper level, but is forced more and more backward by the encroachment of the two neighboring toes. During this process the first phalangeal joint becomes strongly flexed and projects above the level of the first and third toes, which come closer and closer together above its tip. This deformity is kept up by the persistence of the conditions which originally caused it—that is, the continuing to use improperly shaped shoes. All the structures (including muscles, tendons, and especially ligaments) which are made slack by this position contract, the ends of the bones accommodate themselves to the new condition, and rigidity results.

Treatment.—In cases where the deformity has not fully developed, and especially if the subject is youthful, an attempt may be made to correct, or at least lessen, the deformity by passive motion, by the wearing of loose but well-fitting shoes which allow full play of the toes, or by the continued use of some *mechanical device*. *Subcutaneous*

division of the contracted ligaments about the first phalangeal joint has not proved to be of any great value, and *tenotomy* of flexor tendons with forcible extension by which these bands are ruptured has met with only partial success. *Resection* of the head of the first phalanx or of the first phalangeal joint is the operation which is now generally recommended. Although the result is usually an improvement, it is far from being ideal. The first phalanx is apt to remain hyperextended, and there is appreciable broadening of the toe at the point of resection, as a result of retraction of the entire toe. For this reason the toe lies above the gap intended for it, and not in it. Fig. 386 is taken from a

Fig. 386.—Result of excision of the head of the first phalanx for hammer-toe.

Fig. 387.—Result of amputation in hammer-toe. The toes have come together diminishing the gap.

photograph of a case of hammer-toe about a month after the head of the first phalanx had been excised.

Amputation of the Toe.—This is the best procedure for the most intractable cases (Fig. 387). The loss of the second toe does not seriously weaken the foot or interfere with walking. If there should be later a tendency to hallux valgus, as some surgeons claim, great care should be used that the shape of the shoes worn after the operation be such as to give plenty of room for the toes in all directions.

Snap-finger (Trigger-finger).—This is a very rare as well as a very peculiar condition. Owing to some obstacle to the free play of the tendon (usually the flexor) of one of the fingers, there is sudden interruption of flexion or extension, or both, after which time the motion is resumed with a jerk. The condition suggests as a cause that the tendon at one part has become thicker than normal, and that when this affected portion comes to the narrowest part of the canal, it is there arrested temporarily until by force it is pulled through, and the finger, with a snap, is flexed or extended as the case may be. Occa-

sionally a small nodule may be felt on the palm, which corresponds to the thickened portion of the tendon above described. Exactly what this enlargement of the tendon is, and whether it is due to a general thickening of the tendon or to an outgrowth from it, or to the synovial fringes within the canal, is not known.

As for the **treatment,** passive motion may be persistently tried, and if this fails to give relief, an incision should be made, opening the sheath and exposing the tendon, after which any obstacle to the free play of the tendon may be removed.

INJURIES AND DISEASES OF THE BURSAE.

There are two kinds of bursæ in the body—the mucous and the synovial. *Mucous bursæ* are loose irregular sacs in the subcutaneous tissues, containing a clear viscid fluid. They are found over bony projections, such as the olecranon, patella, tip of the os calcis, malleoli, etc. Bursæ similar to these may develop of themselves just under the skin from unusual friction, as on the dorsum of the foot in cases of extreme talipes varus, on a projecting spinal hump resulting from Pott's disease, under corns, etc. *Synovial bursæ* are placed more deeply in the body than the mucous variety. They lie between tendons or between tendons and bone. When they occupy a position near a joint, they are very apt to communicate with the cavity of that joint, as is generally the case in the bursa under the tendon of the subscapularis, also in that between the iliacus tendon and the capsule of the hip-joint, and also in that between the tendon of the semimembranosus and the inner head of the gastrocnemius. All varieties of bursæ are subject to injury, and are especially liable to inflammation and its results.

Injuries of Bursæ.—Bursæ are subject to all forms of injury. The proper treatment of an injured bursa is rest and cold applications. Occasionally bursæ are wounded, especially in operations. They usually heal readily unless infected. If infected, they are sure to suppurate. If there is a penetrating wound of a bursa, especially if there is reason to believe it an infected one, the entire cavity should be laid open and thoroughly cleaned out.

Diseases of Bursæ.—Inflammation of bursæ (bursitis), both acute and chronic, is extremely common. A knowledge of the anatomical position of the various bursæ is often of great assistance in making the diagnosis.

Acute bursitis is generally due to injury, excessive muscular action, or infection. It may also be caused by extension of inflammation from a neighboring joint. The lining of the sac is congested, and fluid is secreted, often with great rapidity. Occasionally there is some blood mixed with the fluid. This condition may result in resolution or suppuration.

Signs.—The part is painful, reddened, swollen, and very tender. If suppuration takes place, there may be a chill, accompanied by sudden rise of temperature and marked increase in all the local signs. Fluctuation will be evident sooner or later. If the abscess is not opened, it will break of itself and discharge, possibly leaving a long sinus.

Treatment.—When a bursa is simply inflamed, an attempt should be

made to cause resolution by immobilizing the part with splint or bandage and placing it in such position as to relax the muscles. Cold (in the form of ice-bags) or hot moist applications should be employed, and in case an undue quantity of fluid is present, the bursa should, if accessible, be aspirated. When pus is present, the cavity should be freely laid open, scraped, cleaned, and drained.

Chronic bursitis may begin as such or may be the result of several acute attacks. Constant friction is also a common cause. Several distinct conditions may result from chronic bursitis: (1) The bursa may be simply distended and filled with a thin clear fluid; or (2) the wall may be considerably thickened, and lined with flabby granulations or with fibrinous deposits, some of which deposits may be free within the cavity of the bursa; or (3) the wall may be so thick as almost to obliterate the central cavity. Suppuration is not uncommon, and in very old cases calcification occasionally takes place. There is good reason to believe that many of these chronically inflamed bursæ are tuberculous.

Signs.—The most prominent, and often the only, sign of a chronically inflamed bursa is a marked bulging under the skin to be seen or felt when the bursa is near the surface; this is due to distention of the sac. Some stiffness may be present, but actual pain is either very slight or absent. If the bursa is a superficial one, fluctuation can generally be made out. This is not so evident, however, when the walls become thicker; in fact, in some cases they are so thick and dense as to give the impression that the swelling is solid. If suppuration has occurred, there is some pain with tenderness, and the skin over the bursa is reddened.

Treatment.—In cases where suppuration has not occurred, aspiration followed by firm compression and immobilization of the part is sufficient to effect a cure; but the bursa is liable to become again distended with fluid, in which case, if it is accessible, it may be freely laid open and curetted and the skin united over it. Complete excision is, however, the best treatment for all except the simplest forms of chronically inflamed bursæ. The bursæ which are most commonly affected, and are therefore brought most frequently to the attention of the surgeon, are those about the knee.

The prepatellar bursa is perhaps more commonly affected than all the other bursæ in the body together. On account of its exposed position on the tip of the knee, it is subject to frequent injuries and much friction, and is liable to all the forms of inflammation. It is so commonly enlarged in domestics as to give rise to the name of "housemaid's knee" (Fig. 388). Occasionally both knees are affected.

The bursa over the tubercle of the tibia is occasionally chronically enlarged on one or both knees. The situation of the swelling over the tubercle of the tibia (Fig. 389) should at once distinguish it from the foregoing.

The bursa under the ligamentum patellæ is occasionally enlarged and tender—a condition which may resemble joint-disease. As Lovett has pointed out, however, there is in inflammation of this bursa undue prominence on each side of the ligamentum patellæ, especially when the knee is semiflexed, and at the same time the normal depressions at both sides of the patella remain unaffected.

The bursa under the quadriceps extensor tendon usually communicates with the joint and partakes in its inflammations, but it may enlarge on its own account, forming a projecting mass about 3 or 4 fingers' breadth above the patella.

The bursa between the tendon of the semimembranosus and the inner head of the gastrocnemius is quite frequently enlarged, forming a glob-

FIG. 388.—Enlarged prepatellar bursa.

FIG. 389.—Enlargement of the bursa over tubercle of tibia.

FIG. 390.—Enlarged bursa between the tendon of the semimembranosus and the inner head of the gastrocnemius.

ular fluctuating swelling at the inner side of the popliteal space, especially prominent and tense during extension of the knee (Fig. 390).

Other bursæ in the body occasionally affected are (1) in the upper extremity, *the subdeltoid bursa* (when it is liable to be mistaken for disease of the shoulder-joint); *the bursa over the tip of the olecranon* (miners' elbow); and *that between the tendon of the triceps and olecranon* (the swelling is on both sides of the tendon); (2) in the lower extremity, *the subgluteal bursæ* (between the gluteal tendons and the great trochanter); *the bursa over the tuber ischii* ("coachman's bursa" or "weavers' bottom"); *the bursa between the iliacus tendon and the*

capsule of the hip-joint; the bursa over the os calcis and *that between the tendo Achillis and the os calcis; the bursa over the outer malleolus* (tailors' bursa); and, lastly, *the bursa over the head of the metatarsal bone of the great toe* (the enlargement of which is called "bunion").

Bunion.—Though the term usually refers to an enlarged bursa at the site above mentioned, it is also applicable to any enlarged bursa over any bony prominence about the toes. When it exists over the head of the metatarsal bone of the first toe, it is almost always associated with an undue prominence of that part of the bone, caused by a deviation of the great toe outward (hallux valgus) (Fig. 391). This deviation in the direction of the toe, and the development of a bunion on the prominent head of the metatarsal bone, are generally, if not always, due to the same cause—viz., the continuous wearing of boots of such faulty shape that all the toes are crowded together and the bony prominences are subjected to constant friction.

FIG. 391.—Bunion with hallux valgus.

A bunion is usually associated with more or less pain and disability. It is especially liable to inflammation whenever the conditions which originally caused the bunion are allowed to continue. Occasionally suppuration occurs, when the pain and tenderness become extreme and the disability complete. If the case is neglected, pus may break through the skin (leaving a sinus), or into the cellular tissue (causing cellulitis in the entire neighborhood), or into the joint (resulting in destructive arthritis).

The most important step in the treatment of bunions is the removal of pressure, and this may be accomplished in the early stages by the use of properly shaped boots or shoes, which should have abundant space in the tip to receive all the toes without crowding. If inflammation occurs, an ice-bag may be applied, or, what is often better, hot creolin foot-baths may be frequently used, the foot being elevated between-times and enveloped in hot moist dressings. If suppuration takes place, the pus-cavity should be laid open freely, scraped, washed with hydrogen peroxid, and drained. If the joint is involved, arthrectomy or even amputation of the toe may be required.

CHAPTER XXIV.

CRANIAL SURGERY.

Anatomical Peculiarities of the Scalp.—When considering diseases and injuries of the scalp it will be proper to remember certain anatomical peculiarities. The hairy skin is intimately united with the tendon of the occipitofrontalis muscle, and together they move freely over the bones of the head, loose connective tissue being interposed between the two. Blood or pus will tend, therefore, to be diffused in contact with the bones, raising the scalp. In exceptional cases this extends over the whole vault of the cranium. There is free communication between the veins outside the skull in the scalp and the sinuses inside the skull adjacent to the brain. Hence inflammation of the veins without extends easily to the veins within. The same may be said of the lymphatic channels. The presence of hair on the scalp in greater or less quantity tends to retain in connection with the skin much dirt, and in injuries of the scalp the most important thing to remember is that the wound becomes infected with great rapidity, and the usual results follow. Inflammation occurring in the scalp will extend and give rise to a great swelling. The blood-tumor so often seen after injury will be under the scalp adjacent to the bone, and may be so excessive as to raise the entire scalp into a large puffy tumor.

INJURIES AND DISEASES OF THE SCALP.

Injuries of the Scalp.—Contused, lacerated, or incised wounds of the scalp are met with, some penetrating to the skull, and others not. It is usual in surgical treatises to consider these various forms of scalp-injury, yet I think that, apart from the recognition of the actual amount of injury existing, as one method of treatment is applicable for all of them, they may be spoken of together. There is no class of injuries which in the past has given more trouble or at the present time is more capable of being rendered innocuous than the class under discussion. The treatment is as follows: The scalp is to be shaved over and adjacent to the seat of injury, cleansed by free scrubbing with a nail-brush, preferably sterilized, using much hot water and alkaline soap, then using alcohol. This cleansing is to be extended to torn and bleeding surfaces. If the wounds are lacerated, as in railway injuries and machinery accidents, and dirt and grease ground into the tissues, by means of the nail-brush with soap, ether, and alcohol the tissues are to be rendered clean. Ragged and very much lacerated edges are to be trimmed off. Wounds extending under the scalp are to be slit up and scrubbed. Briefly, the entire wounded surface is to be treated in such a way that there are no undermined tracks or hidden dirt. Then the edges of the wounds are to be brought together lightly, not tightly, by silkworm-gut

sutures, a voluminous dressing of gauze and cotton is to be applied, and a bandage to hold everything snugly in place. Outside of all a plaster-of-Paris bandage or crinoline bandage will be useful. Such a dressing, if applied over properly cleansed surfaces, can remain without disturbance until healing is complete. It is better not to bring together the scalp-edges closely, for nothing is more certain to induce suppuration than the tension from tight suturing. The bleeding which is usual after scalp-injuries will be arrested by ligature or by sutures passed deeply under a spurting vessel by means of a curved needle. Thorough hemostasis is necessary before the wound is closed.

An incised wound of the scalp does not require a sharp instrument for its production. The vault of the cranium on one side and a flat hard body on the other will press the scalp and so give rise to an incised wound. A fall on the pavement is an excellent example of a straight clean wound produced in this way. Where the injury is over a large surface and rather slanting, not directly toward the skull, a triangular flap of scalp is torn. Occasionally, after the healing of scalp-wounds neuralgia of a more or less pronounced character results. This is due to the entanglement of a nerve in the cicatrix. If the pain does not pass away after the cicatrix is well formed, it may be necessary to dissect the nerve out of the scar, or cut it across proximal to the point where compressed, so as to give relief.

Cellulitis of the Scalp.—Cellulitis of the scalp occurs in both chronic and acute forms. As an acute infection it follows an injury, and the usual symptoms will be present. It extends rapidly, with marked constitutional symptoms, and the resulting effusion rapidly becomes purulent. As the blood- and nerve-supply of the scalp comes from the periphery, sloughing of the scalp and gangrene are not usual; but repair is slow, and unless the pus is evacuated by incisions there is danger of purulent infection through the veins which communicate with the interior of the skull and the diploë; then the prognosis is extremely grave. Circumscribed cellular inflammation is often seen, the result of traumatism with consequent infection. The occurrence of numerous abscesses of the scalp indicates a diminished resisting power of the tissues; it exists with constitutional weakness such as is associated with tuberculosis in children, etc.

Chronic cellulitis of the scalp is often syphilitic, and there is a decided tendency for the inflammatory process to occur in the middle line.

Erysipelas of the Scalp.—This is more apt to be seen as an extension from adjacent parts, notably the face, for, while the scalp can be cleaned and kept clean, the face, edges of the nostrils, etc., where cracks in the skin occur, can never be kept surgically clean. Here erysipelas does not differ from that which is seen elsewhere, except that swelling is greater, and extension by way of the venous and lymphatic channels from the scalp to the meninges is to be feared. The involvement of the whole scalp is, of course, more dangerous than the involvement of only a portion, for thereby more ways of infection toward the meninges will be involved. In negroes the blush of erysipelas will not be apparent if the patient be dark-hued. Great swelling of the ears occurs, and the eyelids resemble bladders of water if they become involved in the disease. Medication will not differ from that called for in the condition occurring elsewhere in the body. The reader is referred to the chapter on Surgery of the Skin, in Volume II. of this work.

It is untrue that sutures of the scalp differ from sutures elsewhere in being more dangerous, as they were considered to be by the older writers. It was the dirty methods employed, and not the sutures, that permitted erysipelas to occur.

Abscesses are met with in the scalp, as elsewhere, either single or multiple. The usual symptoms are present, and early opening called

for. The injection of cocain into the skin—2 per cent. solution—will render the opening painless.

Gangrene of the scalp occurs in two forms: one, the localized condition following severe crush which interferes with the circulation and gives rise to a slough which is cast off, being seen generally in torn ends and flaps which have not been trimmed away by the surgeon; the other is the acute spreading form, characterized by gas in the tissues, and tending rapidly to constitutional sepsis. This is fortunately a very rare disease, and, if successfully treated at all, is to be treated by deep and extensive incisions followed by continuous irrigation, and if this is not possible, then by frequently changed compresses wet with weak corrosive-sublimate solutions or hot water. *Hospital gangrene* may be met with in the scalp.

Carbuncle is seen on the scalp as an extension from the neck, where it is often found. As a primary disease of the scalp it calls for immediate curetting.

Ulcers of the scalp are seldom met with save as an evidence of syphilis. The well-known line at the border of the hair in front may be taken as an example. There is a tendency for syphilitic ulceration of the scalp to occur in the middle line.

Tumors of the Scalp.—Hematoma.—Extravasation of blood under the scalp is evidence of injury, and sometimes gives a clue to the situation of a broken bone.

Pneumatocele.—Two kinds of tumors of the scalp containing air are met with. One of these follows a break in bone communicating with the air-passages—the nasal bone and the ethmoid cells. When the patient attempts to blow his nose, air is forced into the subcutaneous tissue, causing emphysema which may extend over a great portion of the scalp. The ordinary symptoms of emphysema are present, and no harm need be expected to follow. The air is spontaneously absorbed. With the healing of the original injury the tendency for the escape of air into the tissues disappears. The other form is called *pneumatocele*, and means a circumscribed swelling containing air, which swelling is of gradual formation, and indicates a bony non-traumatic defect—developmental, perhaps. The tumor is slowly developed, and sometimes the bony defect will be found at a distance from the point where the gaseous swelling exists. Pneumatocele rarely disappears by itself permanently, but will require incision and packing, or an injection with iodin solution, as may seem best. The most certain way is to close the defect in the bone by plastic operation. A watery tumor under the scalp—cephalhydrocele—will be referred to under Fractures.

Wens.—The most common tumor of the scalp is the wen, or atheromatous cyst, which may occur in any situation, but is most often found beneath the hairy scalp, single or multiple. They vary from very small ones to those the size of a fist, contain the usual sebaceous matter, are sometimes adherent to the skin at one point, and in most cases offer no difficulty of diagnosis. Suppuration is occasionally met with in them as the result of infection from without, possibly by means of the duct, and after the contents have been evacuated inflammation results. Such cases have been mistaken for epithelioma. A

wen is to be removed by incision, care being taken that the entire sac is extracted, otherwise the growth will recur. Unless the tumor is very large, it is only necessary to split the skin freely and turn out the growth; where a tumor is very soft, more care is required to get rid of the sac; but in either case it will come away without difficulty, and must be removed in order to avoid recurrence. It is rarely necessary to close the wound by suture. The edges of the skin come together, and a pad of gauze held by a bandage is sufficient. The line of incision and the adjacent skin are, of course, to be shaved and cleansed before operation.

Dermoid cysts are infrequent in the scalp, though often seen under the outer half of the eyebrow, the situation of a branchial fissure. They are not adherent to the skin, which moves freely over them, but rest in a depression of the skull which may be so deep as to suggest a perforation. To this depression dermoid cysts are adherent. If cut open, hair will be found growing from the inside of the cyst. Excision is the only treatment, and if the cyst is under the eyebrow, an incision in the line of the eyebrow will leave but little scar. Occasionally, though rarely, a prolongation of the dermoid cyst is found within the cranium, and a neck connects the two portions; or one may extend from the temporal region into the orbit. It is important to differentiate between dermoid cyst and a protrusion of the brain or its meninges. The diagnosis will rest upon the fact that the tumor is not situated near a suture, has no appreciable aperture through the skull under it, is not reducible, does not change its tension by changing the attitude of the patient, and is not affected by sneezing, crying, and especially sleeping.

FIG. 392.—Soft fibroma of the scalp.

If removal be performed aseptically, even if a protrusion of the brain be present, no harm will result. Where there is an intracranial and an extracranial portion of the dermoid cyst, the skull is to be chiselled away and the intracranial portion removed.

Horns growing from the scalp have been noted in a number of

cases, and are surgical curiosities. If excision of the base of the horn upon which it is implanted in the skin be done at the time of the operation, the tendency to return will be reduced to a minimum.

Fatty tumors of the scalp are rare. When superficial, there is little difficulty in the diagnosis; when situated under the occipitofrontalis tendon, a diagnosis is impossible without incision. Those that have fallen under my observation were superficial and were not difficult of recognition. One was situated just above the occipital protuberance in the middle line, another above the root of the nose.

Hard fibroma is not met with in the scalp, but a soft fibroma, fibroma molluscum, is not unusual. Such growths are extremely vascular, and excision is to be done after full preparation. The term *pachydermatocele* was given to this form of fibroma by writers in the past. Soft fibroma of the nerve-sheath has been noticed on the side of the scalp near the ear. These tumors may be very hairy, which fibroma molluscum is not.

Keloid.—Keloid attached to the lobe of the ear in the negro is extremely common, but it may appear at any place where there is a scar.

Teratoma.—This form of tumor is found about the head rarely. The tumor is recognized shortly after birth, and grows slowly at first. From the tenth year a more rapid increase is likely to take place. The shape and size follow no rule. A diagnosis is reached by excluding other forms of growth.

FIG. 393.—Teratoma over the occipital bone.

The example presented herewith (Fig. 393) was successfully removed from a child aged fourteen in whom the growth was noticed during the first year and grew very slowly. After the tenth year, however, growth was apparent, and during the eighteen months before operation was rapid. The tumor was found to contain bone and cartilage, striated muscular fiber, and one joint which resembled the shoulder-joint somewhat.

Anthrax of the Scalp.—Anthrax of the scalp is very rare in America, although it is probably met with more often about the face than anywhere else. The usual symptoms will be present.

In a case recently in the writer's care infection was at the back of the neck close to the edge of the hair, and much edema extended to and involved the scalp (Fig. 394).

Vascular Tumors.—Aneurysm of the scalp is rare, usually concerns the temporal artery, and from its situation is easily amenable to treatment. Cirsoid aneurysm may be so extensive as to involve much of the scalp. When adjacent arterial trunks are enlarged and unite, forming a pulsating tumor with small arteries and capillaries pulsating, the growth, fortunately rare, is called aneurysm by anastomosis. There is a distinct bruit, which will disappear when pressure is made on all the afferent trunks. Pressure closing the vessels is the most simple method of treatment, but at the same time one which rarely is successful. Ligature of the vessels afferent to the tumor, with the usual aseptic precautions, will give a good result; should recurrence take place, it may be expedient to dissect out the whole tumor. Communication between an artery and a vein will give rise to dilatation and varicose aneurysm, a condition which was not infrequently seen at the bend of the arm when phlebotomy was popular. If the communication between the two vessels can be found, it is to be closed by ligature, and a favorable outcome follows. The dilatation of a sinus within the head, protruding under the scalp through a deficiency of bone, is referred to elsewhere; the superior longitudinal sinus is always at fault.

FIG. 394.—Anthrax; scalp very edematous.

Blood-tumors of the Scalp.—A blood-tumor under the scalp may occur as an injury at any time, but is met with in the new-born under the name of cephalhematoma, and may give rise to a suspicion that there is a protrusion from within the skull, or that a fracture of the skull during birth has taken place.

Malignant Tumors of the Scalp.—Epithelioma is most frequently seen, is met with in middle or advanced life, and presents the usual appearance and characteristics. It is likely that the subject of the growth will show scaly patches on the face. Extirpation means not only that the scalp is to be removed, but, if necessary, subjacent bone also, so as to get rid of the disease; after which, by plastic operation or by grafting, deficiency in the skull and scalp is to be made good. Secondary growths may appear in the scalp—protrusions from

within the skull or outgrowths from the cranial bones—but they present no features requiring mention here.

INJURIES AND DISEASES OF THE SKULL.

Contusions of the Skull and Incised Wounds not Penetrating the Skull.—The troubles which in the past have resulted from contusions and non-penetrating injury to the skull have been largely caused by infection, which at the present day it is expected will not be met with.

Non-inflammatory Conditions of the Skull.—At birth the skull is but incompletely ossified, and the amount of bone-deficiency may vary. Islands of bone are met with in fibrous tissue, and lines of suture or quite large areas of fibrous tissue may exist with no bony islands whatever. This condition very rarely persists; ossification and gradual closing in of the skull are the rule. Where defective ossification is permanent, a protrusion from within the skull may take place, constituting *encephalocele*, *meningocele*, or *sinus protrusion*.

Great variations exist in the thickness of different skulls as well as between different parts of the same skull. From the twenty-fifth to the fiftieth year the skull is thickest; then gradual atrophy occurs, until in extreme age the cranial bones may be very thin. This is due to an absorption of the diploë and a consequent fusion of the two tables of the skull. The skull of the negro is thicker than that of the white race. Occasionally, however, without known cause, the bones will be found unduly thick, even massive, without diminishing the capacity of the brain-cavity. As the result of rickets (craniotabes), open fontanels, wide sutures, irregular ossification, protuberant forehead, and a softness of the bones which permits of yielding under pressure are met with. Under such conditions no local treatment is indicated in addition to what may be required for the general disease.

Inflammatory Conditions of the Skull.—Acute inflammation of the periosteum is the result of injury with acute infection, and is characterized by the usual symptoms of periostitis. It is more often encountered on the sides of the head, in the neighborhood of the ears. A rigor, fever, and the usual symptoms of inflammation, local and general, are present. Pus becomes diffused under the tendon of the occipitofrontalis, which is raised and gives free fluctuation. Pus tends to sink down in the zygomatic fossa and point near the angle of the jaw. If the temporal muscle is involved in the inflammatory process, the motion of the lower jaw is affected. Phlebitis and the extension of the inflammation to the interior of the cranium through the medium of communicating veins may result. Free incision is called for as soon as a diagnosis is made. A voluminous dressing of gauze wrung out in hot water is to be applied and changed frequently, and the case treated like an acute bone-inflammation elsewhere. The flap of soft parts which has been raised from the cranium by the pus usually readheres; but this is not always the case, and superficial caries of bone may result. Chronic inflammation of the vault of the cranium is met with, but it is rarely painful, is always slow in its progress, and is very apt to be tubercular. When tubercular, it calls for free opening and curetting; iodoform dressing should be employed. Injection of an iodoform emulsion into the cold abscess is sometimes of advantage. Osteomyelitis of the bones of the head is very rare. In diffused form it is rapidly fatal, pyemia or an extension of inflammation from the bones to the meninges resulting.

The **treatment** will be that given in osteomyelitis elsewhere—namely, very free opening through the soft parts, and cutting by chisel or by trephine to the extent that may seem proper. The tendency of such an osteitis is to extend toward the meninges rather than toward the surface; in either case a sequestrum may form, which separates slowly. Gumma of the cranial bones is not unusual, and may result in perforation. Extensive sequestra form, exposing, after removal, extensive areas of granulating dura. Under antisyphilitic treatment the prognosis is fairly good. Sequestra should be removed. The shape of such a sequestrum is generally rounded, with irregular edges. The process of separation is very slow. There will exist one or more openings through the scalp, giving exit to a very profuse discharge. If a portion of the skull through which cranial nerves pass becomes involved, paralysis follows. Fatal inflammation of the meninges rarely supervenes.

Injuries in utero or during birth, from pressure, are occasionally recognized. It is a question whether epilepsy in childhood may not owe its origin to some such injury. The peculiarly shaped heads occasionally met with in young children may result from birth-pressure.

Osteomata of the skull are very rare, and may occur either externally or internally. The latter are called enostoses, and interference with the functions of important parts of the brain may result from them. Exostoses are not so infrequent and are of ivory hardness. In the orbit an outgrowth of bone is met with. They are commoner during the early years of life, and cease to increase when the skeleton has

FIG. 395.—Osteoma of the frontal bone.

attained its growth. The differential diagnosis between osteosarcoma and osteoma is rarely difficult (Fig. 395). The length of time during which the symptoms may have existed usually permits a diagnosis to be made, even though the bone-tumor project into a cavity so as not

to be under the surgeon's fingers. Where the bone projects outwardly there is no difficulty in diagnosis.

Sarcoma may develop in the skull as a primary or a secondary growth. The diagnosis is not difficult, although in its early stages such a growth may be mistaken for a gummatous tumor. Pulsation, if vascular, bruit, and rapid growth will establish the diagnosis (Fig. 396). Where a sarcoma of the skull grows inward, rapid interference

FIG. 396.—Sarcoma of the skull secondary to sarcoma of the jaw.

with the functions of the brain is to be expected. Its increase may be at first either slow or fast, but sooner or later rapid increase takes place. Sarcoma of the skull is probably traumatic in a number of cases. The treatment is free excision together with removal of adjacent parts. The difficulty of effecting this is, of course, evident. If the growth is large, nothing can be done; if small, removal of the bone from which the growth starts and the covering in of the defect by bone from elsewhere are expedient.

Carcinoma of the Skull.—Carcinoma, being an epithelial product, occurs in the skull only secondarily.

Leontiasis.—This name is given to a diffuse enlargement of the cranial bones. Its name and the appearance of the skull strongly suggest tubercular leprosy.

CEREBRAL LOCALIZATION.

There are certain areas upon the cortex of the brain, not necessarily co-extensive with either lobes or convolutions, whose functions are accurately known. These areas are: 1. The sensorimotor area. 2. The speech areas. 3. The visual area. 4. The auditory area. 5. The area of sensations of smell and of taste.

The *sensorimotor area* includes the cortex of the anterior and posterior central convolutions which border the fissure of Rolando and the adjacent cortex in front of and behind these convolutions. Each hemisphere controls movement on the opposite side of the body; but as the right hand is more generally used and is better trained than the left, this area is larger on the left hemisphere than on the right.

The cortex of the posterior part of the second frontal convolution controls the movements of the eyes and head. Impulses starting from this area produce conjugate movement of these parts toward the opposite side. The eye district is below, the head district above. The lower third of the anterior and posterior central convolutions governs the movements of the face, tongue, larynx, and pharynx. The eyebrows and cheeks are controlled by the upper and forward part of this

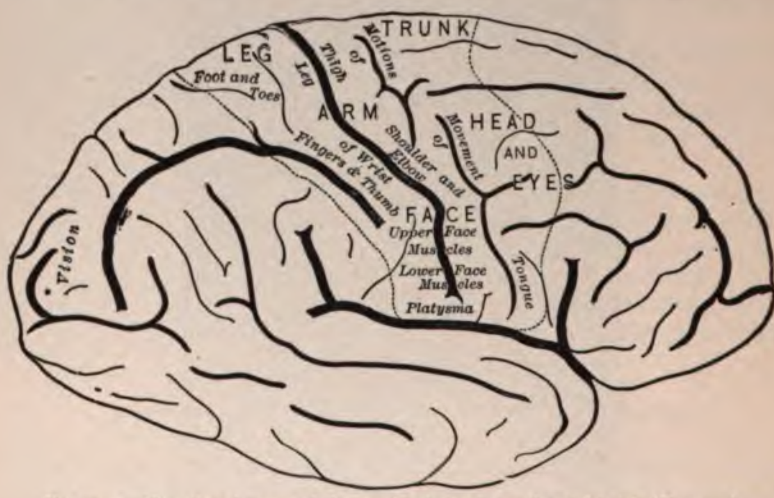


FIG. 397.—Functional areas of the cerebral cortex on the right side (Dercum).

area; the tongue and larynx, by the lower and forward part; the mouth, pharynx, and platysma, by the hinder part.

The middle third of the anterior and posterior central convolutions governs the movements of the upper extremity, the shoulder-motions being controlled in the anterior and upper part of this area, the elbow-motions in its middle part, and the hand- and finger-motions in its posterior and lower part. The upper third of the anterior and posterior central convolutions, including their junction in the paracentral lobule, controls the motions of the lower extremity, the thigh, knee, foot, and toes being governed by various parts of this area from before backward in the order named.

It will be noticed that the parts susceptible of the finest and most delicate movements, those directed by the most acute sensations—the lips, the fingers, and the toes—lie farthest back in the motor area, chiefly in the posterior central convolution. Lesions in this convolution almost always cause some loss of tactile sensation in addition to paralysis, and hence this area is thought to be the seat of tactile sensations as well as of movements.

There are no sharply-defined sections of the motor area to be assigned to special motions. Each motion, each part of a limb, has a

wide general representation over the cortex and a special representation at a limited area. Horsley says that the areas of representation of different limbs merge into one another; thus, in the representation of the thumb we find that there is a focus, but that the thumb is represented over a great deal of the upper-limb region, and that this representation diminishes in intensity gradually as we pass from the focus upward. This explains the fact that the excision of a small area does not totally paralyze the portion of the limb represented chiefly on that area. The adjacent areas represent to some extent that limb, and hence can govern it if need be.

The *speech-areas* are of four kinds and in four locations. They are limited to the left hemisphere in right-handed persons and to the right hemisphere in left-handed persons. There is the *motor speech-area* in the posterior part of the third frontal convolution, in which the movements concerned in the act of speaking are controlled. The use of language and the power of talking are affected when this region is

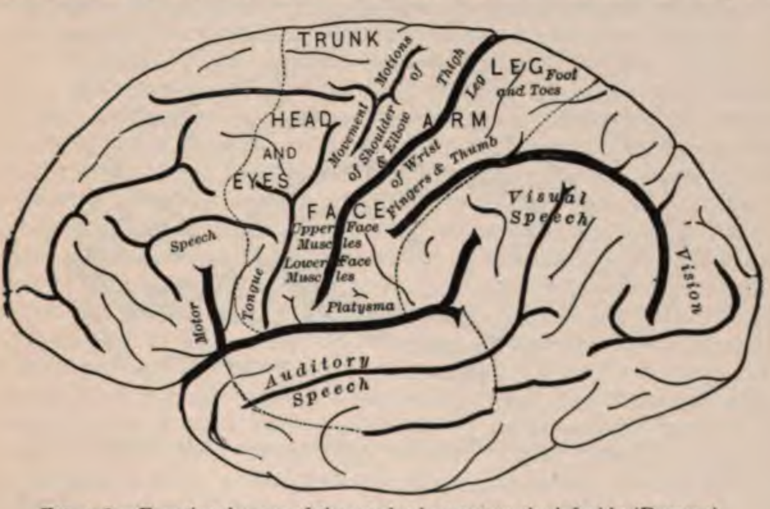


FIG. 398.—Functional areas of the cerebral cortex on the left side (Dercum).

destroyed. There is the *auditory speech-area* in the first and second temporal convolutions, in which the memories of word-sounds are stored up. The understanding of language and the power of recollecting the names of objects are lost when this region is destroyed. There is the *visual speech-area* in the lower parietal region, in which the memories of printed words are stored up. The understanding of written language and the power to read are lost when this region is destroyed. The power of writing is a part of speech, and is usually lost when the motor speech-area is destroyed, but its exact location is not fully determined; some cases point to the second frontal convolution, others to the lower parietal convolution near the hand-center, as its probable cortical position.

The *area of sensations of sight* is located in the occipital lobe of the brain, including the cuneus on the median surface and the occipital convolutions on the convexity. The cortex lying in the calcarine

fissure is the part primarily reached by the visual impulses, but the parts named are also concerned in vision. Each occipital lobe receives impressions from one half of both eyes, hence a lesion in one lobe produces hemianopsia, a half-blindness in both eyes, the blind field of vision being on the opposite side to the lesion.

The *area of sensations of sound* is located in the first and second temporal convolutions of the brain. Each ear is connected with both hemispheres; hence deafness from a unilateral lesion is only partial, and is not generally noticed. On the other hand, if both temporal lobes are destroyed, the patient becomes totally deaf.

The *area of sensations of smell and taste* is located at the tip of the temporal lobe, on its under and inner surface, which rests on the sphenoid bone. Each lobe is related to sensory organs on both sides, and a unilateral lesion does not often produce noticeable symptoms.

There appears to be a certain relation between the frontal lobes of the brain and the higher forms of intellectual activity, the powers of fixing the attention and of reasoning and self-control; but disease

FIG. 399.—Median surface of the right hemisphere (after Ecker).

here does not cause a loss of any one mental faculty, and for the higher powers of the mind a general integrity of the entire brain, not of any one part, is necessary. When it is considered that every concept is made up of numerous memory-pictures joined together, each of which has a separate location in the brain-cortex, it becomes evident that to the process of thought a healthy state of the entire cortex is necessary, and also of the white matter beneath it, through which the associating fibers pass. It is therefore impossible for a single lesion anywhere to cause a loss of memory, or of imagination, or of judgment. Yet for the co-ordination of facts into orderly series, for comparison, and for analysis of knowledge gained through the senses a healthy state of the frontal lobes appears to be necessary. Lesions in the frontal region, especially upon the left side, are quite uniformly attended by mental dulness, apathy, lack of power of concentration, and imperfect self-control.

The cortex of the hemispheres upon the base of the brain lying on the orbital plate, on the sphenoid and temporal bones, and on the ten-

torium cerebelli has as yet no assignable functions, and lesions in these regions do not produce recognizable symptoms.

The crura cerebri, pons, and medulla contain the centers of the various cranial nerve-nuclei, and hence cranial nerve-palsies are caused by disease in them. They transmit motor and sensory tracts to the spinal cord, hence numerous symptoms appear when they are injured.

The cerebellum, lying in the posterior cranial fossa beneath the tentorium cerebelli, controls the equilibrium of the body; hence disturbances of the nature of staggering and vertigo are produced by lesions affecting it, especially if its median lobe is involved.

It will thus be seen that cerebral localization has to do mainly with two fissures—the fissure of Rolando and the fissure of Sylvius. It is important that the relation between the external surface and the various cerebral convolutions should be capable of recognition; otherwise, operations undertaken through the skull would necessarily be much in the dark. To find, then, the fissure of Rolando the following method is to be adopted: Trace a line along the vertex from the root of the nose to the posterior occipital protuberance, and find the middle of this line. From a point $\frac{1}{2}$ inch posterior to this middle spot draw a line downward and forward, making an angle of 67 degrees with the middle line. This line will lie over the fissure of Rolando. Two metal strips joined at an angle of 67 degrees are usually employed to find the Rolandic fissure, the place of joining being made to correspond with the point already referred to. If one limb of the angle be placed along the median line, the other will correspond to the Rolandic fissure. The Rolandic fissure is about $3\frac{1}{2}$ inches long, and the lower end of it dips rather suddenly down from the middle line, and therefore the last half-inch does not quite correspond to the strip of metal. The fissure of Sylvius is found as follows: From the lower margin of the orbit to the external auditory meatus a line is to be drawn. Draw a second line, parallel with the preceding, from the external angular process of the frontal bone backward $1\frac{1}{4}$ inches, then upward from the end of this $\frac{1}{4}$ inch; mark this point 1. From the top of the parietal eminence draw a line downward, perpendicular to the base line, and mark a point $\frac{3}{4}$ inch below the eminence; this is point 2. Join points 1 and 2, and the line will lie over the fissure of Sylvius. The Sylvian fissure is about 4 inches long.

CONTUSION AND CONCUSSION OF THE BRAIN.

This is met with to a greater or less extent as an accompaniment of violence to the skull. Mild concussion occurs without structural change of the brain. Where the concussion is greater, it will be proper to use the word "contusion" to indicate the cerebral injuries, which may be small capillary hemorrhages. This may take place with or without fracture of the cranium. The contused portions of the brain may soften or be absorbed, scar-tissue subsequently resulting. It is rare for abscesses to form, since bacteria, in the absence of a wound, could reach the injured locality only by the circulation.

Contusions of the brain occur not only at the point struck but at the opposite side—counter-stroke—of the skull. Contused areas also occur

in other portions of the brain than those immediately opposite the seat of injury. A still more extensive injury to the brain than "contusion" is called a "laceration." In this the amount of hemorrhage may be increased, so as to justify the term "intracranial hemorrhage." It is not always possible to differentiate between concussion and contusion in their varying degrees. Contusion necessarily implies concussion, but concussion may exist without contusion. There are several theories as to the cause of concussion—one, that the vibration is transmitted to the brain, another that the fluid within the ventricles is violently displaced—both of which are accepted by eminent authorities.

The **symptoms** present will vary with the injury to the brain. After a concussion with momentary unconsciousness the patient may recover promptly and go on with his vocation. A more severe concussion is followed by a period of unconsciousness, feeble circulation, pale surface, and relaxation of the muscular system, from which recovery is slower. Vomiting may take place with the beginning of recovery. Relaxation of the sphincters occurs rarely, and only when the concussion is severe. Dissimilarity between the symptoms on the two sides of the body will indicate something more than concussion—a contusion with injury to one hemisphere more marked than the other. The greater the contusion to the brain and the greater the effusion of blood, the more slowly will the patient recover. Recovery may be preceded by delirium, mental disturbance, and excitement. Should any portion of the brain, however, suffer special injury, the symptoms will point to that part. When contusion and disorganization of brain-substance have taken place, not only will shock be prolonged, but repair may be expected to take place slowly, varying, of course, with the amount of contusion. The function of that part of the brain which suffered contusion may be permanently impaired. The contusion, if the violence be great, may go on to the extent of laceration and destruction of a sufficient amount of brain-substance to produce death.

The **diagnosis** between concussion, contusion, and apoplexy is one of degree, and unless the symptoms indicate injury to a definite region of the brain, it may be difficult. The symptoms mentioned under the head of Intracranial Hemorrhage must be held in mind. The temperature in concussion will probably be subnormal; in contusion, unless immediately after the receipt of the injury, the temperature will be a little elevated, and may be expected not to fall to normal at once, the time depending upon the amount of intracranial lesion. From alcoholism the diagnosis of concussion depends largely upon the ability of the physician called to see the patient to recognize the odor of alcohol upon the patient's breath. Yet alcoholic patients are frequent subjects of concussion, owing to their inability to retain their equilibrium.

The coma of uremia must be differentiated from intracranial violence as well as from alcoholism. The rule should be absolute that the urine of an unconscious patient brought into hospital should be examined at once, a catheter being used. Should no urine be present in the bladder, the clothes of the patient will show whether any has been passed recently; and in the absence of urine either in the bladder or on the clothing a strong suspicion of uremia is aroused. If urine is found to contain albumen and casts, etc., the diagnosis is made. Of course,

it is not impossible that a uremic patient may fall and hurt his head, but the uremia is the important point. An injured man, if transported a certain distance, his body lightly clad and exposed to cool air, will show albuminous urine when he enters hospital, yet by the next day it may not be present. This is due undoubtedly to the chilling of the surface.

Treatment.—A diagnosis is first made, if possible, then reaction is to be induced by proper methods, but should not be allowed to be too violent. Rest in a recumbent posture is required with the head low, if the pulse be weak, and hypodermics of strychnin. If the surface be cold, dry heat should be applied. As the symptoms improve or the reverse, so will treatment be changed. Large hot enemata of water containing two ounces of black coffee seem to be beneficial where collapse is profound. The amount of strychnin which can be given under such circumstances is large: $\frac{1}{30}$ gr. every half hour until four doses have been given. For restlessness, laudanum in a little black coffee, say 2 or 3 drops every quarter of an hour, is given by the mouth. If the unfavorable symptoms be not relieved, the foot of the table may be elevated, but only when symptoms of brain anemia are present. If the symptoms still fail to improve, it is possible that some sign pointing to a definite portion of the brain may appear, and to this the surgeon should direct his treatment.

FRACTURES.

Anatomical Considerations.—The cranium is made up of bones intimately united along certain lines of suture, which permit of no movement between adjacent bones save in the very young child. These bones, especially in the base of the skull, are perforated so as to permit the passage of important structures. The spinal canal joins the cranial cavity at the foramen magnum. The bones of the vault of the cranium are made up of two plates of bone with intervening cancellated structure, the outer table thick and strong, the inner table thin and brittle.

The amount of cancellated tissue varies with age. Wanting in early childhood, in adult life it is found in its greatest extent, and then by absorption diminishes in old age. Hence in the very young and the aged the cranium is thinnest. There is a notable difference in the thickness of the bones forming different skulls, and this apparently without the existence of disease. In early childhood the bones move somewhat upon each other; during and after youth, not at all. The sides of the head, the squamous portion of the temporal bones, have little or no diploë. The base of the skull is composed of cancellated structure almost entirely, thin plates of bone only covering in the cancellated structure. Air-cells are developed during adolescence and adult life in certain portions of the skull—for instance, the frontal and ethmoid sinuses. These sinuses do not diminish in size with advancing years as does the cancellated tissue in the vault of the cranium, but remain permanently. The free communication of veins between the inside and the outside of the skull has been referred to already.

Incomplete fractures—that is, fractures not extending through both tables—are rarely met with except where the frontal sinuses exist. As there is separation here between the two tables, much injury may be done to the forehead and yet the brain-box not be broken. If the fracture of the frontal sinuses be compound, the secretion from the mucous membrane lining the sinus may be mistaken for brain-tissue.

Incomplete fractures of the cranium elsewhere are usually the result of knife- or sabre-wounds delivered with much violence, which shave off a flap of cranium and bone together. Incomplete fracture is of importance only so far as it has to do with the complications, such as sepsis, for instance. Fractures of the inner table are referred to later.

Fractures of the cranium are considered under the heads of Simple, Compound, Comminuted, Complicated, Complete or Incomplete, Direct or Indirect, Fissured, etc., as are other fractures; but it must be kept in mind that every fracture of the cranium is complicated by the close vicinity of the brain and its coverings, and that it differs in this respect from fracture of other parts. The shape of the skull, as a whole, being roughly that of a globe, it breaks, when subjected to violence, in a manner quite different from the skeleton elsewhere. Not only the point where the injury is received may give way, but the violence will travel to a distant region and in some cases cause a fracture, the intervening bone remaining intact. In like manner, transmitted violence may be expended not upon bone, but upon the dura, which closely adheres to the inner surface of the skull, producing rupture of a blood-vessel and intracranial bleeding. In other instances the brain itself will receive the violence, and disorganization of the nervous matter result. Injury to bone always is to be held of secondary importance, the matter of first importance being the injury to the nervous system. This should never be forgotten.

Fracture of the Vault of the Cranium.—Fracture of the vault is usually the result of direct violence applied over a limited surface. If, on the other hand, violence is attended by much momentum, the force is diffused, and a fissure may be found to travel from the point struck to some distant region. A quick sharp blow, then, produces a local fracture; violence with momentum, a fissure. The direction in which the fissure travels is not always certain, and the mechanism by which it is produced is not always plain. In injury to the vault of the cranium from without, the inner table will be fractured over a larger area than the outer table, and a comminution of the inner table may take place and one or more of the fragments be turned on edge, so as to irritate the adjacent dura. If violence be done from within the skull, as by a pistol-bullet passing through the skull, at the wound of exit the outer table will be broken over a larger area than the inner. As an extremely rare condition the amount of violence may be sufficient to break the inner table without fracture of the outer table. An example of this is in the Medical Museum at Washington.

A sudden sharp blow, breaking the vault, will depress the bone, which gives way along several lines. The amount of depression will depend on the violence and the shape of the vulnerating weapon. The apex of the depression will press against the dura, which may give way, so that the brain is torn by the rough bone-edges, while the sides of the cone-shaped depression will be the fragments of skull driven in but remaining attached to the unbroken vault. Should the violence be extreme, fragments of bone are detached from the skull and driven bodily into the brain. The inner table is always more extensively comminuted than the outer table, although the dura will give way to a less extent than the outer table.

Depression of bone sufficient to force in the dura without causing that membrane to give way is liable to contuse the brain and cause subdural hemorrhage. Permanent depression of bone without fracture does not occur except in very early life, yet a portion of cranium may be forced inward and give way in the line of several fissures, resuming its normal position when the force is removed; these fissures are apparently insignificant, yet they are plainly fractures.

Fracture of the skull without depression is apt to take the shape of a fissure, which may be compound, with or without depression; if depression exist, effusion of blood under the intact scalp promptly fills the depression and raises the scalp so as to mask the injury. If the scalp gives way, there is external bleeding, and the depressed bone is plainly exposed to sight and touch.

Brain-shock, then, is to be accepted as a first result of injury to the vault of the cranium; whether this shock be accompanied by hemorrhage or disorganization of the brain or not, the observer will not be able at once to recognize. Depression of bone can generally be made out by careful examination, although the scalp may not be divided. If there is much effusion about the seat of injury, and the scalp is not divided, recognition of the fracture is difficult. Attention should be directed to the fact that after an injury to the scalp with effusion of blood between the scalp and the skull, the periphery of the effusion in the course of two or three days becomes hard, while the center remains still soft, thus giving to the examining finger the sensation of a depressed fracture, when in fact the bone is intact. Excellent surgeons have been misled by this. Gentle and steady pressure will usually suffice to press aside any effusion or clot, and enable the examining finger to recognize fracture if any depression be present. Where a fissure without displacement exists, such an examination is negative. When a diagnosis is uncertain, the surgeon should not hesitate to divide the scalp and inspect the injured region. Aseptic precautions are, of course, called for.

A fissure-fracture starting from the vault where injured will generally travel toward the base, and there is a general tendency for fractures in the front or middle or posterior part of the vault to extend toward the fossa at the base of the skull corresponding to the portion of the vault injured. Fissures of the anterior portion of the skull are apt to involve the roof of the orbit and anterior fossa; those of the posterior part of the head, the cerebellar fossa; and those of the central portion of the head, the middle fossa of the base. The fissure which begins by running horizontally will usually turn downward toward the base, but the mechanism by which longitudinal fissures of the cranium are produced is not well defined. In depressed fracture the lines of fracture will, of course, vary with the violence and its direction, also the amount of depression and the amount of comminution. Occasionally, although violence has come from without, a fracture of the vault of the cranium has resulted not in a depressed but in a raised fragment of bone. In these cases a pointed missile—chisel—has entered the skull and pried the broken portion above the surrounding surface.

Fracture of the base is usually considered as occurring not by direct violence, but rather by counterstroke, *contre coup*. This latter is

the case where fracture of the base follows an injury to the vault, the intervening bone being intact. But where violence done to the vault results in an injury which travels from the point struck down into the base, in the form of a fissure, it is more accurately described not as counterstroke, but as direct violence travelling continuously along the skull wall. The mechanism by which the fracture by counterstroke takes place has been variously, but not always satisfactorily, explained. The most probable view at present is that from the point where the violence is received a wave is transmitted through the semi-fluid brain and delivered at some distant point, producing a fracture there. This would be more easily understood if the cranium were a perfect sphere, and the region of the counterstroke fracture were always directly opposite where the violence is first received. Such is not the case, however, and therefore various buttresses in the skull itself are regarded as tending to diffuse shock, and thus produce fracture in a somewhat irregular way. It is considered that the vault of the cranium is ribbed anatomically, the ribs running up toward the vertex from the frontal region, the external angular process of the frontal, the mastoid process, and behind from the occipital protuberance. In the middle line in front, from the root of the nose upward, a rib may be considered to extend, and rarely if ever will a fracture passing from the vertex downward follow these ribs, but always run between them. The transmission of violence along the walls of the cranium was at one time the accepted theory. I scarcely think that at the present day any one view of the counterstroke will be found to apply to all cases. Where the fissure starts from the point struck and extends continuously into a distant part of the cranium, there is no doubt that the shape and consistence of the bone have much to do with the line of fracture. Counterstroke injury is not, however, limited to bone-tissue, for contusion of the brain and rupture of blood-vessels may occur, both of which are of infinitely more importance than the fracture of bone.

Fissure-fractures pursue their course independently of sutures. When violence is done to the vault of the cranium, it is probable that a certain amount of depression takes place, and that the bone from its own elasticity regains it shape. If the violence is continued until the bone gives way, the bones may or may not resume their shape. Where a fissure has been produced and the bones have taken their position again, diagnosis without a wound of the soft parts is not possible. In a certain number of cases of this kind the vulnerating force has carried hair against the bone (compound fractures), which hair has been caught in the fissure, and, on inspection, appears to be growing directly from the bone.

In childhood, when the bones are softer and more elastic than later, having little cancellated structure, a depression without fracture may exist.

The *roof of the orbit*, when broken, gives way most irregularly. There are instances of fracture of the roof of the orbit where the fracture was comminuted and the fragments were turned up on edge so as to irritate the dura. The anterior fossa of the base has been broken by injury received on the occiput, counterstroke giving rise to

comminution of the orbit roof. The case of a late chief magistrate of the United States who suffered fracture of both orbital plates from a pistol bullet-wound of the occipit has become classical. The anterior fossa of the base is occasionally wounded by direct violence through the orbit. Cases are recorded where an umbrella-point or a foil has been thrust through the roof of the orbit, the skin-wound being so small as to escape notice, so that the fracture was not recognized until fatal meningitis had occurred. The anterior fossa may suffer injury by direct violence through the nose. The middle fossa of the base of the skull is more often broken than either the anterior or posterior, though rarely by direct violence. The break is generally due to a fissure which extends from the vault through the root of the zygoma and the petrous portion of the temporal bone, breaking the tympanum and possibly extending to the basisphenoid. The cerebellar fossa, as has been already said, is more apt to be broken by injury done to the back of the skull, and the fissure will be found running more or less forward from the point struck, and may open into the foramen magnum.

Prognosis of Skull-fracture.—There is generally an increasing mortality in fractures of the cranium from before backward, the least mortality attending fractures in the front, and the greatest mortality in the occipital region; this applies both to the vault and the base. Perhaps the supposed larger mortality in the occipital region may arise from the fact that cases escape our observation, and the severe wounds alone are recognized.

Puncture fractures may of course occur anywhere, and are characterized by a small wound both in the soft parts and in the cranium, perhaps insignificant in appearance. The inner table of the skull will be broken to a greater extent than the outer, and fragments of it are apt to be carried into the brain. Septic matter is frequently inoculated, so that operation is called for. In gunshot wound, operation is not always indicated. The anterior fossa of the skull, as well as the middle fossa, is in relation with cavities by which inspection becomes possible—namely, the nose, the orbit, and the auditory canal. In suspected fractures of the anterior fossa, effusion of blood is very apt to travel forward in the sheath of the optic nerve and spread out over the ball of the eye, making its appearance as a subconjunctival hematoma. This may extend up to the cornea and obscure the sclerotic. Subsequent to this hemorrhage the lids or intra-orbital tissues may become edematous and discolored, but always after the subconjunctival effusion. Ordinary "black eye" from contusion is very common, but here, the lids being separated, the eye will be found normal. If fracture should take place through the olfactory plate, much blood would be expected to flow from the nose; but bleeding from the nose is such a very common accident after head-injury that as a diagnostic sign it carries very little weight. Fracture of the middle fossa of the skull will give rise in certain cases to bleeding from the ear. Here the fracture has torn the drum of the ear, and has extended through the middle ear and petrous portion of the temporal bone, opening the subdural space. Under such conditions, the flow of blood, ceasing in twenty-four to thirty-six hours, is succeeded by a flow of watery fluid, first blood-stained, then clear. This is cerebrospinal fluid, and is highly characteristic of a

fracture in the locality stated. In one or two cases the bleeding has been followed by a limited flow of water, and yet subsequent examination has not shown that the fracture extended into the subdural space so as to give exit to cerebrospinal fluid; here it is believed that the fluid poured out is from the labyrinth. It is a surgical curiosity, and is so rare that a flow of blood from the ear followed by watery fluid may be taken as diagnostic of fracture into the middle fossa, opening the subdural space. The apertures through which the cranial nerves pass may be involved in a fracture, and the implication of the corresponding nerves, with disturbances of their function, will assist the surgeon in making a diagnosis.

In case a depressed fracture or a hemorrhage involves the motor area, valuable information as to its extent and situation may be afforded.

Healing Skull-fractures.—Fractures of the skull heal with little callus. When loss of bone is extensive, the hiatus will rarely be closed by bone. Strong fibrous tissue bridges over and fills up the opening, and occasionally contains small fragments of bone. This scar-tissue may be so firm as to give to the examining finger a sensation of bone, and a dissection may be necessary in order to recognize the material with which the defect is closed. Reimplantation of bone after fracture with loss of bone may sometimes close a defect, and in other cases necrosis after a certain period will necessitate the removal of the implanted bone. Repair of skull-fractures is slow.

FIG. 400.—Part of frontal bone and nearly all the roof of the orbit removed for mental disturbance following depressed fracture one year previously. Complete recovery.

The Treatment of Skull-fracture.—A depressed fracture of the skull (vertex) which is allowed to remain unelevated may give rise to most serious symptoms —epilepsy, etc.; and since clean operations on the skull are followed by a minimum of risk, it is allowable at the present day, in a case of uncertainty, to incise the skull over the supposed fracture, and by sight and touch recognize the condition of affairs (Fig. 400). This is better than the uncertainty of a possible depressed bit of bone.

For elevation of depressed bone the trephine is very rarely needed. The sharp corner of the chisel can generally be inserted between some of the depressed fragments, and, one after another, they can be raised into position or removed. It is essential to examine carefully the under surface of depressed fragments, and make sure that all the loose pieces of the inner table have been removed. The dura is to be carefully

examined, and repaired by suture if torn; and where there is any doubt

FIG. 401.—Simple depressed fracture of the skull in an infant, without symptoms. No treatment. Gradual disappearance of depression (Elliot's case).

on the subject, broken bone had better be removed entirely than left with a possibility of setting up future trouble. That a depressed fracture will necessarily kill a patient if let alone is not true. In a certain number of cases epilepsy develops as a result of such pressure, but in some others absolutely no symptoms are recognized, and the patient leads as useful and as long a life as if there were no depression whatever. These are the exceptions only, and the occurrence now and then of such a case is to be looked upon as a surgical curiosity, and not as an index to treatment. Rough edges are always to be smoothed, and then the scalp closed over the seat of operation. Arrest of hemorrhage is to be effected by ligature, and the scalp closed lightly and not tightly, as advised under Treatment of Scalp-wounds.

FIG. 402.—Loss of bone (traumatic) 3 by 4 inches.

Fracture of the base is unfortunately not easily got at, so that the treatment will not be so direct and

cleanly as where the vertex has suffered injury. Unquestionably, many cases of fracture of the base recover, but the prognosis is always grave, especially where the injury occurs by means of a wound in relation to the air. This is the case when the tympanum and temporal bone are fractured and torn, as shown by the flow of blood and cerebrospinal fluid. Here it is manifestly impossible to get at and clean the vicinity of the fracture. Likewise, where the base of the anterior fossæ is opened and the nares put in communication with the interior of the skull, the difficulty of cleansing is at once apparent. When the posterior fossæ suffer fracture, as there is no opening normally existing through the skin, much doubt must exist in regard to the condition of affairs present. In either case cleanliness, when obtainable, should be exercised. Absolute rest in a recumbent posture is to be enjoined, a darkened room and absolute quiet insisted on, while a light and very abstemious diet is to be given, and a purgative administered daily.

The treatment directed elsewhere in this article, when an operation for the removal of a head-tumor is undertaken, is the treatment to be carried out with skull-fracture—the same cleansing, care of the wound, and closure of the wound with dressing.

Gunshot wounds of the head are usually penetrating and always compound, and are serious more from injury of the bone of the meninges than of the brain itself. A glancing injury from a bullet is extremely rare, and much rarer with the modern projectiles than when a more slowly moving bullet is employed. The glancing bullet, sup-

FIG. 403.—*a*, Gunshot fracture, showing fissure; *b*, crush of the skull; comminuted fragments wired lightly.

posing that such a thing is now seen, will produce a contusion of the skull, with such accidents as may result therefrom. A gunshot wound of the skull with the modern army weapon produces in many cases very great injury, which has been denominated "explosive violence." A bullet passing through the skull will produce fractures running in every direction, as though great violence from within had been expended on the bones. The bullet always traverses the skull, producing two wounds; such injuries are promptly fatal. The explanation given is that the bullet, in its very rapid passage through the semi-solid contents of the skull, expends its force on that mass in every direction. There is not time enough for the cerebrospinal fluid or for the blood to be displaced so as to make room for the bullet, so a rending of the cranium takes place. This has been experimentally tried and verified by vessels filled with water, even although the top may not have been

tightly pressed down. Pistol-bullet wounds or non-fatal gunshot wounds of the head are met with. Here the bullet does not travel with as much velocity, and may lodge. The injury is a complex one, and will always be complicated by a forcing into the brain of fragments of skull. The symptoms will depend upon the part of the brain injured, and paralysis of some portions of the body, extensive bleeding, or immediate death may take place. Theoretically, the treatment to be followed out is to cleanse thoroughly the field of injury, to place the patient's head in such a position that the track of the wound shall be vertical, with the external opening above, and to allow a probe to sink by its own weight through the brain-track, and if the bullet have struck the opposite side of the skull, to trephine there, open the düra, locate the bullet, and extract it, leaving the trephine wound open for drainage. Practically, very few cases of such excellent surgery have been successful, while by conservative methods recovery with the bullet remaining in the brain has ensued. In case it should be deemed unwise to search for the bullet within the skull, the patient's head should be placed in such a position that drainage shall take place outward through the opening in the skull, so that the fragments carried into the brain may make their way out, and possibly the bullet come near the external opening, so as to permit of removal. A number of cases are on record of recovery with the bullet remaining in the brain. Where the bullet has entered the skull, apart from the immediate danger from the injury, secondary abscess-formation is to be feared. Here the usual symptoms of brain-abscess will prevail.

Generally speaking, then, the treatment of a gunshot wound of the brain is local cleanliness, first and most important—shaving the scalp, etc. Then, if the fragments of bone which have been carried into the brain do not present at the opening, or if the bullet do not present, unless there seem to be special indication, it will be unwise to trephine and search for the bullet. The probe which should be used to investigate the track of the bullet through the brain should have a large end and be sufficiently long to pass through the skull. A probe with a small point will easily penetrate the brain-substance and so mislead the surgeon. An aluminum probe or a Nelaton probe with a slender shank is best. It is unwise to close a gunshot wound of the head. Before attempting to remove a bullet from the brain, it should be localized as closely as possible by means of *X*-ray photographs taken in two or more directions, so as to give the point by means of intersecting planes.

INJURIES AND DISEASES OF THE BRAIN.

Hemorrhage may be extradural, subdural, or central. Extradural hemorrhage is usually the result of a rupture of one of the middle meningeal branches, with or without break of the skull, the effusion of blood taking place between the bone and the dura. Subdural hemorrhage may be from bleeding into the pia arachnoid, in which case it is from the middle meningeal vessel, or it may be upon the surface of the brain, when it will be from the rupture of one of the vessels of the pia mater, with tear of the arachnoid. In either case the internal capacity

of the skull, so far as the nervous matter goes, is diminished by the amount of blood effused. If the blood be poured out quickly, symptoms of interference with brain-function will soon appear. On the other hand, where the hemorrhage is slow, the cerebrospinal fluid is slowly pressed from the cranium into the spinal canal, and symptoms of brain-disturbance appear gradually. When the effusion is between the dura and the skull, the necessary stripping off of the dura from the skull will exercise some compression upon the mouth of the bleeding vessel. If the clot be opposite some portion of the brain presiding over motion or speech, local symptoms peculiar to a lack of function in that portion of the brain will appear. On the other hand, if an effusion of blood takes place into the subdural space, the blood will gravitate to the base of the skull and will press upon the basal ganglia, so that general rather than special symptoms of compression will be apparent. When the bleeding is under the pia arachnoid, due probably to a tear in one of the veins, it takes place slowly, the effused blood, spreading out in a more or less thin layer, clots on the surface of the brain; it dips down into the sulci, and may give rise to localized convulsions from irritation, or to paralysis, if it be over a motor area. With these local symptoms the general symptoms of compression will be present. These local symptoms will decidedly assist a diagnosis. Irregularity of the pupils will suggest hemorrhage.

Extradural hemorrhage is almost always from the middle meningeal vessel, and the first local symptom of compression will probably come

FIG. 404.—Extradural hemorrhage from rupture of the middle meningeal artery (from fracture shown in Fig. 405).

from that part of the brain lying adjacent to this artery. Loss of power occurs on the side opposite to the place of pressure. There is often an interval between the infliction of violence and the symptoms of compression due to intracranial hemorrhage. During this period

intelligence is retained, although it may be disordered. This is the most important symptom. The following sequence of events is pathognomonic and calls for interference at once: Injury, concussion, recovery, a period of intelligence followed by hemiplegia, somnolence, unconsciousness, and irregular movements. The temperature will not be elevated; the pulse will be slow and full, but with increasing compression, may become rapid. The breathing will at first be quiet. Convulsions may occur. Later the breathing becomes stertorous, and some rise of temperature takes place. Dilated pupils will be found to accompany the late stage of compression, whereas at its commencement the pupil is contracted. A dilated and immovable pupil strongly suggests a local compression. If trouble be limited to the left side, aphasic symptoms will be more apt to occur with hemiplegia, in a right-handed person. In the right side hemiplegia without speech-disturbance is usual. Hemorrhage may cease spontaneously, but the pressure on the

FIG. 405.—Fissured fracture of skull crossing the middle meningeal artery. The hemorrhage resulting from this fracture is shown in Fig. 404 (Elliot's case).

brain will continue to exist until the clot is absorbed, and mental disturbance will persist until then. A clot may never be entirely absorbed, and may cause irritation in the same way that a depressed fragment of bone may cause Jacksonian epilepsy.

Injury to a sinus of the dura may happen from direct trauma and hemorrhage may occur, or the bones may be forced in upon the sinus and the hemorrhage not take place until the bone is elevated. By pressure with gauze, by suture with fine thread, or by passing a ligature with a curved needle around the sinus, it may be arrested.

Treatment of Intracranial Hemorrhage.—The treatment already suggested for concussion and contusion of the brain will be proper for intracranial hemorrhage until a diagnosis is made. When that is evident, the recumbent posture and an ice-cap become necessary, together with measures to reduce the force of the heart-beat. The symptoms continuing, it is a question whether operative interference is called for. When there is any probability that the effusion is due to a rupture of

the middle meningeal artery, the skull should be opened without hesitation, the clot removed if present, and the bleeding vessel tied, if possible. A curved needle carrying a thread is passed under the vessel proximal to the wound. The opening in the skull should be large enough to permit of all manipulation, and if the first opening is not sufficient, it should be made sufficiently large by means of rongeur forceps. Failure to find the clot under the trephine-wound may occur, but the absence of pulsation under the dura and the discoloration of the dura will suggest a deeper clot. The skull having been largely opened, the dura is to be incised a sufficient distance—$\frac{1}{4}$ inch—from the edge of the bone, to permit of sewing up afterward. The dura then is turned down, and the clot evacuated by spoon and a gentle stream of water, the bleeding point being sought for and tied. If the hemorrhage is from a vein of the pia, it will be found with much difficulty.

Hemorrhage into the lateral ventricle presents no symptoms differing from an intracranial hemorrhage not in the motor region, except greater liability to convulsions.

Hemorrhage into the brain-substance may take place from direct violence with fracture and depression, and will be subject to the usual treatment of fracture with depression; but a violent contusion of the brain without fracture may occur, and the contusion may be sufficiently severe to give rise to hemorrhage into the brain-substance. Such hemorrhage is usually punctiform, but may be worthy of the name of extravasation, if the amount of blood poured out be large. In such a condition of affairs there would be present the violent jar of the primary injury, from which the patient might recover, and then would become apparent the symptoms resulting from the extravasation of the blood into the brain-substance. If compression-symptoms were progressive, it might be proper to open the head and attempt to find the bleeding point; but the operator would probably be unsuccessful. If the symptoms are not progressive, it would be useless to open the head with the expectation of removing the clot; more harm would result to the brain from the operative measures than from leaving it alone.

Hernia Cerebri.—This name is given to a protrusion of the brain-substance uncovered by membranes through an opening in the skull. It occurs after fractures or wounds with loss of skull in which the meninges have given way or been divided. It is an evidence of sepsis, local perhaps. The protruding mass, which is brain-substance, at first is small; it subsequently may become large, may slough, may suppurate, but always projects above the level of the skull. It will pulsate and is soft to the touch, not vascular, however; it is possible to cut away portions of the hernia, for brain-substance is insensitive. When portions of the hernia are cut away, new portions are apt to protrude through the skull. As inflammation diminishes, the hernia will sink within the head and cicatrization take place, or the patient may die of general sepsis (Fig. 406).

Treatment.—An attempt to force the brain back into the skull will give rise to symptoms of compression not advantageous to the patient. Cutting off pieces of the brain down to the level of the skull is not

called for. A clean dressing, with a light compressing bandage to hold the dressings in place, and so exercise a very slight pressure on the hernia, is all that is necessary. The surface of the hernia may slough, and if so, the dressing should be changed and cleanliness con-

FIG. 406.—Hernia cerebri.

tinued. As the wound becomes clean and cicatrization takes place, the hernia will disappear.

Brain-compression.—The amount of compression to which the brain may be subjected will vary with the rapidity with which the compression is effected; and this may be explained by the escape of cerebrospinal fluid from within the head into the spinal canal, thus permitting a foreign substance to occupy space within the cranium without causing pressure on much of the brain-substance. To produce this change compression must be effected very slowly. A rapid compression will give rise to local effects at once. Probably from 3 to 6 per cent., or thereabout, of the intracranial area can be taken up by a foreign substance without the symptoms of compression becoming marked. After the above maximum, however, has been passed, pressure-symptoms may be expected. It is on account of this that extravasation of blood may go on from a ruptured vessel, if the rupture be small, for a certain time, without giving rise to symptoms; or the growth of an intracranial tumor may take place and attain a decided size without giving rise to symptoms whereby its presence would be noted. It may be that where an abscess forms in the brain, the pressure-symptoms are not noticed at first. The primary symptom may be one which results from the involvement of some specific brain-area —for instance, in the motor region. Inasmuch as the escape of cerebrospinal fluid from the head relieves compression, for a certain time, at all events, it is evident that an excess of pressure, if such increase take place slowly, may happen without disturbing the brain-function, as is frequently the case in hydrocephalus.

The **symptoms** of compression are mental disturbance—which may be sensory or motor—irregular movements, vomiting, and progressive loss of consciousness, running into coma, with snoring when sleeping,

and convulsions. The convulsions may be more marked in one part of the body than in another, which will give rise to a well-grounded suspicion as to the locality where the compressing force is most exercised. Breathing and pulse are both slow in compression. Optic neuritis, if compression has existed a certain time, will be found; disturbance of vision also, and of smell and taste. Indeed, all the cranial nerves should be investigated, and while in general compression they may tell nothing, yet they may give some indication in the early stages of a compressing growth.

The **treatment** of compression is naturally to take away, if possible, that which compresses.

Open Wound and Laceration of the Brain.—Laceration of the brain occurs under very many circumstances and shows very many symptoms, both primary and secondary. There will always be a certain amount of shock as a primary symptom, and there will be very generally a certain amount of infection which will give rise to inflammation. The portion of the brain which is lacerated is to be considered. As a rule, a wound of the anterior brain gives rise to much less mortality than does a wound of the posterior part of the brain, while laceration of the base of the brain is the most promptly fatal of all. Lacerations of the brain of the most desperate nature have been recovered from, while fatal symptoms have followed a very minor injury. Unless a portion of the brain essential to life suffers laceration, it is probable that infection produces the fatal result. In the absence, therefore, of infection, laceration of the brain may be looked at not so very unfavorably. It is practically impossible to cleanse the lacerated surface of the brain, hence the absence of infection is an accident due to the cleanliness of the vulnerating instrument.

The part of the brain injured, whether in the motor area, the area of speech, etc., will have to do with the symptoms which present. A slightly elevated temperature may be met with, but not always, and the pulse, simply from the laceration of the brain, does not seem to be changed markedly. After forty-eight hours, when inflammation due to infection appears, there will be seen the symptoms due to meningitis; the temperature will be high, and indeed in some cases will be found to go up after death. Occasionally, the temperature varies on the two sides of the body. There may be multiple lesions within the head, giving rise to very confusing symptoms. Inequality of the pupils is more apt to be due to the hemorrhage and pressure. Unconsciousness is more often due to a concussion or jarring of the brain than to laceration. The mental condition after laceration of the brain will vary greatly with the region of the injury.

Traumatic Meningitis.—Meningitis is an evidence of infection. Acute meningitis is an infection due to injury, and means that septic material has been carried to the meninges, and that such cleansing as was done by the surgeon was insufficient to remove the inoculated sepsis. From this as a primary focus the disease may extend. Probably the organism which gives rise to the inflammation has much to do —more than we have hitherto suspected—with the course of the inflammation, otherwise it is difficult to know how meningitis in one case is circumscribed and promptly followed by the recovery of the

patient, while in another case the patient rapidly dies, with all the symptoms of constitutional poisoning. Meningitis extending to the base of the brain is extremely fatal, and is to be guarded against by immediate and thorough cleansing and by affording drainage.

Secondary Meningitis.—Secondary meningitis by extension from the seat of trauma occurs, indicating that during convalescence a failure to keep the wound clean has occurred. Veins or lymphatics may carry an infected clot to the meninges, or the clot may be carried by direct continuity of tissue. A meningitis commencing from an injury will be most pronounced in the vicinity of that injury; but when once inflammation has taken place, there will be cloudy or purulent cerebrospinal fluid, with exudation. Constitutional sepsis is a rapid sequel of meningitis in most cases. It may extend not only to the base of the brain, but to the spinal canal. The ordinary clinical symptoms of weak and rapid pulse, elevated and variable temperature, delirium, hyperesthesia of the surface, restlessness, retained urine, constipated bowels, intense headache, glistening eyes, trembling and busy hands, followed by stupor, hebetude, contracted pupils, which often do not react to light, make up a picture which admits of little doubt. Should meningitis be more pronounced along the fissure of Rolando, local spasms or paralyses are to be expected. The results of treatment are not favorable. Attention to the secretions, rest, removal of all exciting causes, the application of an ice-bag to the head, cool sponging if the temperature be high, strychnin to support the pulse, will probably be all that is to be done. Whether the free opening of the skull and an attempt to obtain drainage is to be followed by good results, it is impossible to say; but this much is certain, that when inflammation occurs in a closed cavity, it is always important to have that cavity opened, so that the products of inflammation may find an exit and tension be relieved. Where a fissure-fracture has travelled to the base of the skull, basilar meningitis is very apt to follow, and, inasmuch as many important cranial nerves are given off from this part of the brain, a disturbance of their function will be noted. However, the inflammation is rarely limited to the base of the skull, but extends to the upper part of the spine, and so retraction of the head and interference with and disturbance of the upper spinal muscles are likely.

Sinus thrombosis is believed to occur most often in middle life, although as our experience increases it is not at all improbable that both childhood and old age will be found to be subject to this distressing condition. It is the result of infection, and while occasionally following traumatism, is more often seen as the result of middle-ear disease. The lateral sinus is usually the vessel affected. For this subject see Vol. II. Chap. XXVIII.

Brain-abscess.—It is proper to distinguish acute from chronic abscess. The acute form succeeds an injury and gives rise to the ordinary symptoms which one would expect from an abscess. Evidences of sepsis are always present; high pulse and temperature exist. Abscess of the brain is, of course, the result of infection, which may be carried by traumatism, but may reach its situation through the blood-vessels or lymphatics, as in other parts of the body. Along the perivascular sheaths infection may pass to the place where we find the

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abscess. Perhaps in this latter case the abscess will be in the neighborhood of the ear—a frequent source of infection. The limiting membrane of a cerebral abscess is granulation-tissue. The pus may be thick, and may be variously colored, from admixture of coloring matter of the blood, or possibly organisms (pyocyaneus). The pus is inodorous if thick; if thin, it is apt to be of bad odor. If a vessel gives way, blood will be poured into the abscess-cavity. Symptoms of compression will scarcely bear an exact relation to the size of the abscess. Chronic abscess comes on very insidiously and may not be diagnosticated at all. The onset of symptoms is slow and progressive, the temperature usually subnormal, while the pulse gives evidence of compression more and more marked, but this at a late period, not at first. Vomiting, irregular pulse, and irregular chills are encountered; but the last-named symptom will be seen attended by disturbance of temperature to the extent of several degrees (Fahrenheit). When an abscess makes its way to a surface, external or ventricular, rupture and a fatal meningitis will ensue. The prognosis is distinctly bad, whether acute or chronic abscess be present.

An acute abscess of traumatic origin will present symptoms of local sepsis, as mentioned above, sufficient to justify a decided opinion as to its presence and location. A chronic abscess will often tax to the utmost a surgeon's knowledge of cerebral topography and overtax his power of localizing the disease. Perhaps of all symptoms, pain, more or less pronounced, is the most constant, yet it is referred sometimes not to the seat of disease, but to some other portion of the head; percussion will increase the pain, and the patient will regulate his movements so as to avoid jar to the head; sudden change of attitude—*e. g.*, rising in the morning—may bring about vomiting. The symptoms mentioned will increase as the disease progresses, and hebetude, disinclination to make effort, and stupor will be added; yet evidence of motor or sensory disturbance of the brain or interference with the function of cerebral nerves is needed that the locus of disease may be discovered. It is unnecessary to repeat here what has already been said in regard to cerebral localization.

Treatment.—A brain-abscess after localization is opened by making an incision of sufficient size through the skull, using a trephine and enlarging the aperture with rongeur forceps. The exposed dura is observed for pulsation, change of color—necrosis—and then opened as directed in the section on Intracranial Tumors. Pial vessels can be tied between two ligatures and divided, after which by a grooved director the brain is explored and the abscess opened. A pair of forceps passed into the abscess along the groove of the director will enlarge the track for discharge of matter. The abscess-cavity is to be cleansed by means of the curet and a stream of sterile normal salt solution, and then drained—by tube, if deemed expedient.

Intracranial Tumors.—Surgical localization and clean surgery have rendered possible not only the recognition, but also the removal of tumors within the head, which formerly were interesting only up to the point of diagnosis, for after that relief, save by medical means, was not to be expected. Intracranial tumors present for consideration certain questions: Whether the tumors are single or multiple, whether

they are individual or expressions of a constitutional condition, whether they are primary or secondary, whether they are local, circumscribed, and capable of removal in their entirety, or whether they are diffused among adjacent structures and incapable of being taken away, the portion necessarily left continuing to grow. Inasmuch as they are not subject to sight and touch, stress must not be laid on their characteristics.

Age.—Starr's Tables, although published some time ago (in 1893), do not differ materially from our knowledge of the present day. Thus he gives:

Tuberculous cases	in childhood,	152	to	41	in adults.
Gliomatous tumors	"	37	"	54	"
Sarcomatous "	"	34	"	86	"
Gliosarcomatous	"	5	"	25	"
Cystic	"	30	"	2	"
Carcinomatous	"	10	"	33	"
Gummatous	"	2	"	20	"
Not stated	"	30	"	41	"
Out of a total of 600	"	300	"	300	"

In this table the preponderance of tuberculous tumors in childhood is apparent. Sarcoma and gliosarcoma show a preponderance for the adult. The carcinoma, as would be expected, is more common in the adult, and the cyst largely among children, the proportion being very great—30 as compared with 2. Equally the gumma is largely in excess in the adult. A large number of cases of syphilitic disease of the brain from an infection many years previous improve under treatment and recover; hence, it is improbable that gumma of the brain is more common than the tables show.

Glioma and sarcoma are probably not to be differentiated the one from the other, and they should be considered together in their symptoms and treatment. They are usually primary in the brain. As a secondary growth of the vault of the cranium growing inward, I have met with sarcoma several times, but secondary to a primary eye-growth sarcoma is not very infrequent. Glioma and gliosarcoma may grow from either white or gray matter, and are more often diffuse than circumscribed; and when I say diffuse I do not mean infiltrated, for this they undoubtedly may be, but I mean not definitely surrounded by a connective-tissue capsule. Probably glioma is softer, more vascular, and of more rapid growth than sarcoma, as a general rule; but in special cases the reverse may hold. Involvement of the brain may take place as a direct extension from the eye back from within the orbit, the primary growth being in nerve-tissue. Sarcoma of the bones of the skull projecting inward may occur, but such cases are never so difficult of diagnosis as when the tumor starts within the brain-substance, and this is so for two reasons—first, because the growth may make its appearance outside the bones of the skull and so be recognized; and secondly, because, by growing inward, the cortex is pressed upon and definite symptoms produced, which will certainly be the case if the motor area be involved. Of the cause of sarcoma we know nothing. Injury to the head, as in other parts of the skeleton, might give rise to malignant growth; but in just what way traumatism should be applied so as to injure the inside of the head seems to be somewhat indefinite.

Primary carcinoma of the brain is rare. It may arrive by direct extension from an epithelial surface, as when an epithelioma of the scalp perforates the skull, or it may appear in metastatic form. In the latter case the foci may be multiple. As usual with carcinoma, it is more apt to be met with in the latter half of life.

Cysts occur with complicating malignant growths, as the result of irritation from depressed bone, or as a changed condition of an intracranial clot. Cysts may be due to parasites, as hydatid, but will be very rarely encountered in this country; they are of slow growth and give rise to no symptoms by which they can be distinctly differentiated.

Tubercle has already been spoken of as occurring in childhood more often than in adult life, and it is a question which presents itself whether the growth be single or multiple. Unquestionably, in many cases a tubercular nodule is not single. A primary nodule of tubercle must be very rare in the brain; it may be secondary to a growth existing in the body, yet entirely unknown to the patient and incapable of being reached by the surgeon. It is scarcely necessary to say that where the presence of such a growth is in question, the personal and family history is to be carefully reviewed, and the patient examined completely in hopes of gaining a clew in regard to that very important point—the expediency of an operation. The prognosis will be unfavorable unless the probability of multiple growths can be eliminated, and even then the uncertainty attending the diagnosis must be ever present, and the prognosis correspondingly guarded.

Gumma.—Here local evidence of previous infection is to be sought for by an examination of the patient stripped. Previous history is to be investigated. It is always proper, so uncertain is the diagnosis of intracranial tumors, where an intracranial tumor appears likely, to institute antisyphilitic treatment, which should be pushed rapidly until it becomes apparent that no favorable result is to be expected from a continuance of such treatment. It does not seem reasonable that the diagnosis of gumma is to be accepted because of temporary improvement, for mercury may act as a good general tonic. Temporary improvement has followed the institution of antisyphilitic treatment in a patient suffering from sarcoma of one of the long bones. Hence a diagnosis of intracranial gumma cannot be made unless the patient is not only temporarily but decidedly and permanently improved.

The Situation of Intracranial Tumors.—They occur in the cerebellum during childhood probably twice as often as in the adult; on the other hand, the cortex in the adult is the seat of tumor three times to once in the child. A tumor which commences in the base of the brain—the basal ganglia—in the internal capsule, can, with difficulty, if at all, be reached; indeed, tumors situated here are usually considered to be out of the field of operation. On the other hand, the convexity and sides of the brain are open to operative measures, with the prospect of affording relief. It is probable that 6 per cent. of brain-tumors are removable. Fibroid of the dura and an exostosis from the cranial bones are distinctly simple tumors producing local symptoms, and can be subjected to operation with every prospect of recovery; but with the other tumors mentioned the prognosis is always grave. The geographical diagnosis will rest entirely upon the localization in different

portions of the brain of certain functions—as has already been stated—in addition to which the interference with the function of cranial nerves must be taken into consideration. With a tumor in the frontal region certain mental and character changes are to be expected. The patient will experience less self-control, become more irritable than usual, and his moral nature will be impaired. Blindness from pressure is one of the later symptoms, and may be expected; optic neuritis is frequent, beginning on the side where the growth exists, but later involving both eyes; vomiting and convulsions occur. Protrusion of the eye may occur, and this without direct pressure on the roof of the orbit; probably this has to do with interference with the return circulation behind the orbit; I have noticed it more than once. Occasionally there will be local congestion of the subconjunctival vessels or eyelids. In the parietal region, in the neighborhood of the fissure of Rolando, there will be interference with the motor tract, and a tumor commencing here will give more marked symptoms than anywhere else. Aphasic symptoms vary with the fact as to whether the patient is right- or left-handed, the center for language being in Broca's convolution; while in the temporal lobe auditory aphasia may be produced. In making a diagnosis certain conditions, characteristics, and growth of intracranial tumors deserve notice. The advent of symptoms is very gradual, and according as certain areas become involved, so does the patient develop new symptoms, which may be in the form of general convulsions or local spasms, paralysis, awkward motion, or interference with known nerve-function; the different functions of which the patient in health is capable must be investigated in order to recognize any departure from the normal. A careful study being given, the surgeon will still be in doubt in no inconsiderable number of cases. Local tenderness on percussion over the tumor may be present; the percussion note may vary on the two sides of the head. Attention has been drawn to what has been called the cracked-pot sound on percussion, which is believed to be due to loosening of the sutures; I am not sure, however, that any very decided opinion can be drawn from it.

Spasms are met with in lesions commencing in the cortex—Jacksonian epilepsy—and in the later stages of other growths by pressure involving the cortex. A gradual extension of motor symptoms, according to the known order of centers about the Rolandic fissure, is diagnostic. As pressure-symptoms increase, so mental effort becomes distasteful to the patient, and hebetude, dulness of thought, and a change in the mental characteristics appear. The mind becomes more and more clouded, and the patient exhibits disinclination toward mental activity; a slow and full pulse is to be expected. Sight and hearing, taste and smell, and interference with speech are to be investigated, and attention paid to the parts of the brain presiding over these special senses. Persistent headache in one locality will suggest the situation of a tumor. Unconsciousness or vomiting without reason is rarely seen without marked pressure-symptoms; intracranial nocturnal pain is suggestive of a syphilitic lesion. Dizziness may be complained of in stooping, or when the head is in a more or less recumbent position, suggesting undue vascularity of the growth or surrounding area, which becomes congested when the head is held downward. Defective articu-

lation suggests involvement of the motor nerve of the tongue; numbness may also exist; knee-jerk and ankle-clonus are to be investigated.

Cerebellar tumors are often accompanied by headache; vomiting and vertigo are met with in a certain number of cases; and while general convulsions may occur from tumors anywhere in the head, in the cerebellum they are perhaps more often met with; nystagmus occurs. A staggering gait is marked, the patient staggering usually to one side, and generally from the side upon which the tumor exists, yet not always. Where the patient exhibits a tendency to fall directly backward, the middle portion of the cerebellum is apt to be pressed upon. Hemianopsia may be present when a cerebellar tumor exists. Retraction of the head may occur; external strabismus suggests a pressure on the sixth nerve and an affection of the eye on the same side as the tumor. Optic neuritis exists generally.

Expediency of Operation.—When the question of operating upon an intracranial tumor presents itself, the operator must ask himself several questions. First, Is there a tumor at all? second, Where is it? Is it in a part of the brain accessible to surgery? Is the tumor single or multiple? Is it a local tumor, or is it but the expression of a constitutional vice, the removal of which will not cure the disease? Is it metastatic, the original focus being elsewhere? Is it a malignant tumor, which involves more brain than can possibly be removed, so that a portion of the tumor will be left after the operation to grow again? All of these questions should be answered with fair accuracy before an operation is undertaken. It goes without saying that multiple growths and metastatic growths should be let alone. Tumors incapable of being removed should be let alone. A tuberculous tumor, if recognized, should be taken away. It may be that there is no other focus except the one operated upon—at all events, the patient should have the benefit of the doubt.

Gummatous Tumor of the Brain.—Whether or not such a tumor should be operated upon is a difficult question, because of the diagnosis. If antisyphilitic treatment in large doses continued for some time does not cause absorption, operation should be attempted; but from the fact that treatment was not efficacious in removing the growth, the operator would probably be of the opinion that the tumor was not syphilitic. In general it may be said that with present methods of opening the head the removal of a tumor is not such a very dangerous thing; and inasmuch as the outlook without an operation is bound to be fatal, much risk may be taken by the operator in the hope of doing good; so where the diagnosis is reasonably clear, an operation should be undertaken.

Technic of Operating.—Very few operators are so thoroughly familiar with the skull and the brain that they can dispense with a sawed skull and a cast of the brain for reference during an operation. The convolutions of the brain vary in different people. A portion only of the brain is exposed to view during operation, and it is not always possible to recognize that which is in view. By means of a battery and proper electrodes it is possible to stimulate the motor areas and produce definite movements, so that the exposed convolutions can be recognized. The entire head is to be shaved, and any evidence of previous injury

or disease carefully noted. The usual aseptic precautions having been taken, an anesthetic is administered and the operation is begun. It is a good plan in intracranial operations to use chloroform as an anesthetic, for congestion of the brain and meninges is thereby lessened. The two extremities of the fissure of Rolando are to be located, and with the burr passed through a small incision in the scalp the skull is marked, so as to show the course of the fissure after the scalp has been reflected. This, of course, is done only where it is necessary to reflect the skin. A large flap, consisting of scalp and bone—osteocutaneous—is to be turned down, so as to expose the brain where desired. The base of this flap is directed toward its blood-supply—the temporal or occipital artery, as the case may be—thus assuring its vitality. A small flap is embarrassing from failure to expose the brain sufficiently, and a large flap is no more dangerous than a small one; so the flap is cut with a knife down to the bone, the bone cut and forcibly pressed outward, so as to give way at its base. The hemorrhage is to be arrested by hemostats or ligatures passed with a curved needle under the skin. I have not been able, by encircling the head with an elastic band, to arrest bleeding as I desired. In the line of incision, then, the bone is to be cut, and here the operator exercises his own fancy. I prefer the chisel, others prefer to trephine and cut through the bone with proper forceps or the electric saw. The chisel gives good satisfaction. Several chisels of different shapes will be needed. The bone having been cut through, its base may be cut somewhat across to facilitate breaking, then the whole flap turned down. Bleeding from the bone is sometimes excessive and inconvenient. It usually stops with a little pressure; if not, the edge of the bone at the bleeding point may be crushed in with heavy forceps, or Horsley's putty can be rubbed into the cut edges. The surface of the dura is examined, and it is cut $\frac{1}{4}$ inch from the divided bone and a flap turned toward its vascular base. Any bleeding points are tied with fine silk. If the tumor present, it can be removed; if it should not present, then it may be wise to enlarge the opening in the skull with rongeur forceps, so as to expose more brain; or it may be that the tumor is covered by the brain, so that the brain will have to be opened. Palpation will enable one to recognize the consistency of the brain, and also probably whether there is a tumor under the cortex. It is better to make a cut into the brain-substance than to puncture it; the latter procedure is misleading, for, if a soft tumor is present, it may be of the same consistency as the brain, so that puncture will reveal nothing. It is well, then, to incise the cerebral substance and investigate with the fingers. To avoid bleeding from the pia, curved needles carrying fine silk or catgut are to be passed under the vessels and tied. This can be done with advantage before an attempt is made to remove the tumor, in order to prevent hemorrhage. The consistency of the tumor will determine the method of its removal; the handle of a knife, or the finger, the handle of a spoon, etc., may be used. Hemorrhage from the site of the tumor, if excessive, is to be arrested by ligature or gauze pressure. The wound is closed by putting the dura back in position and stitching it, and by bringing up the osteocutaneous flap and suturing it in position. The bones may be united by suture, or it may be that suturing the scalp in place will hold

the bone; this can be decided at the time of operation. I think it wise that in most cases a piece of gauze should be left, so as to drain any blood which would otherwise accumulate in the bed of the tumor, and the base of the flap-bone can be cut away, so as to give exit to the drain. The dura is stitched with fine silk, and the scalp with silkworm-gut, but the suture-material is a matter of no importance. At the end of forty-eight hours I remove the drain. A voluminous dressing completes the operation, and this dressing may require removal if the flow of cerebrospinal fluid be very great. After one intracranial operation the flow of cerebrospinal fluid was so great as to wet through three folded sheets in the first twenty hours.

Protrusions from Within the Skull.—Protrusion of the membranes from within the skull is always congenital, and is called *meningocele*. It is congenital, and more often seen in the occipital region or in the neighborhood of the orbit. It is more or less extensive, and is to be considered as essentially of the same nature as spina bifida. Meningocele will present in a line of normal suture or where there is a bone-defect. If the protruding membrane contain cerebral tissue only, the tumor is a *meningo-encephalocele*. It is not always necessary that such a tumor should be seen upon the surface of the skull; it may protrude through the base, and is found in the nasopharyngeal cavity. The tumor will be elastic, will fluctuate, and it may be that the examining hand will recognize fluid as well as solid contents. They are generally partly—in some rare cases perhaps entirely—reducible within the skull by pressure; but symptoms indicating brain-pressure are produced when such a tumor has been made to disappear entirely within the head. Again, such actions as coughing, sneezing, crying, which tend to produce congestion within the head, will always produce increased tension in the protruding tumor. During sleep a partial subsidence of the tumor is noted, as well as a diminished tension. Prognosis is not favorable, few such children living beyond a very short time.

Treatment.—Little that is favorable can be said. Inasmuch as spina bifida has been operated on of late years by excising the sac, or at all events much of it, and stitching the base of the tumor, a similar operation may be tried with a tumor of the kind under consideration. If no brain-substance be in the sac, a more favorable prognosis can be made; but it is possible that the tumor can be reduced and the sac tied off or stitched off at the opening of the skull, and then the aperture in the skull closed either by stitching the soft parts over it or by making a covering of the outer table of the skull with its periosteum. Pressure by means of pads, bandages, etc. does not seem to have been beneficial or to have induced a cure of such growths.

Hydrocephalus.—A term applied to cases in which fluid collects in the ventricles, distending the brain and head (hydrocephalus internus). The condition is essentially chronic, may be congenital, and generally occurs during childhood. Influenced by the collection of fluid in the ventricles, the brain expands and sulci are obliterated. With this progressive increase in bulk of the brain the cranium spreads, enlarges, sutures are separated, fontanels elevated, and the appearance with which one is familiar is established. The prognosis is distinctly grave. In the early stages of hydrocephalus the diagnosis is difficult,

if not impossible. When the skull is enlarged and takes its characteristic shape, diagnosis is easy.

Treatment.—For medical treatment the reader is referred to medical treatises. Suffice it to say that the only operative treatment that offers possible advantage is aspiration, or perhaps drainage. The operation of tapping is done through the anterior fontanel, or through the line of a suture between the bones, if it should be thought best. Strict attention to asepsis is absolutely required. Drainage from the ventricle has been tried by a number of surgeons, but it is not an operation that can be generally done with advantage or can be confidently recommended. Withdrawal of fluid from the spinal canal, and therefore from the cerebral ventricles, can be easily done by puncture with a fine trocar passed between the laminæ in the lumbar region. As a diagnostic measure it offers opportunity to investigate the cerebrospinal fluid and the organisms therein, but scarcely seems to be a therapeutic measure by which excessive secretion of this fluid shall be prevented. It is, however, a method by which direct application of drugs can be made to the central nervous system.

Aneurysm within the Head.—Diagnosis of aneurysm within the head is extremely difficult, and it is doubtful if certain knowledge of its existence can always be obtained. The symptom which is most relied upon is the aneurysmal bruit; and if the aneurysm is in the neighborhood of the eye, protrusion from the orbit may occur. The presence of a growth, bony or otherwise, which diminishes the caliber of the artery within the head will give rise, however, to a similar bruit to that upon which the diagnosis of aneurysm largely rests. Pressure upon the parent vessel without the head will cause the bruit to cease, but this will be the case whether the vessel is dilated or whether an exostosis exist. The patient is conscious of the sound, which is extremely disagreeable. If in the neighborhood of the cavernous sinus, the blood-current through the veins will be interfered with, but this is as true of an exostosis as of an aneurysm. A malignant growth pressing on the vessel would give rise to a bruit, but here the increase of symptoms would take place more rapidly than if an aneurysm were present. The only **treatment** that offers prospect of recovery is to tie the parent vessel—usually the internal carotid—and this it will be proper to do on the affected side, if the symptoms become unbearable.

TREPHINING.

Trephining for Imbecility.—If imbecility were always the result of a known condition of affairs in the brain, there would not be much difficulty in arriving at a conclusion as to whether trephining is beneficial or not; but in view of the multiform causes, both congenital and acquired, of defective intellect, the expediency of trephining is most uncertain. Probably the most sensible way to look at it is to consider that imbecility is a symptom, and then to discuss the question as to whether trephining will relieve it by removing the cause. It is perfectly plain that when an undeveloped brain is present, trephining will be useless. When there is arrested development, no good is to be expected. When intracranial tumors or clots exist, it is possible that

some benefit may result; but the cases which are to be benefited are those in which there is some definite lesion which a surgical operation can be expected to remove. If the imbecility be due to such a cause, in removing the cause the trephining will benefit the condition of imbecility; but without this, one can scarcely expect any good to follow an operation. When the changes are in the brain-tissue, as from an excess of connective tissue (porencephalus), good is not to be expected. Of late years and in a large number of cases the scalp has been reflected and the head has been opened very extensively, for the purpose of permitting an increase of growth and development of the brain. These are supposed to be cases in which the brain is unduly small. A favorable result has been reported a number of times shortly after operation, as though the operation had acted as a stimulant to the development of the brain. Probably it would be just as well if we knew the result after a year or two, then we might form an idea as to whether improvement reported immediately after operation had continued, and whether the improvement was not temporary, or whether a relapse to the original mental condition did not take place. The dura in such cases has never been opened to an extent equalling the cranial cut, and the amount of enlargement which was given to the intracranial space was probably not very great. At all events, before we decide as to the expediency of such an operation, some light on the subject is wanted.

Trephining for Epilepsy.—Trephining for epilepsy is one of the early operations of which we have record, but, having been often unsuccessful because performed in cases not suited for it, it was done more and more rarely. At the present time it is employed in certain cases only, and yet still, unfortunately, it yields only moderate success. The cases in which trephining produces a cure are those to which attention was called by Hughlings Jackson—namely, those in which the epilepsy is the result of a definite cortical lesion, and the epileptiform convulsions become general only after having given indications of local origin. Thus there will be an indication, sensory perhaps, but more likely motor, of some special region, which the patient will appreciate; after which there will follow indications of motor disturbance in the cortex of the brain adjacent to that in which the trouble has commenced, and then by extension the convulsions become general. Thus there may be disturbance of a finger or the thumb, and then of the hand, wrist, forearm, arm, etc., the convulsion always commencing in the thumb, and spreading thence. In such a case it would be proper to open the skull over the thumb-center, which might be found diseased, either from adhesions of old inflammation or from a cyst, or a tumor, or a growth of some kind. It would then be proper to remove the adhesion or the growth, or even, in the absence of any gross lesion, to excise the center presiding over the portion of the body first affected, in the expectation of removing the source of trouble. In traumatic cases a depression of bone, or a loose spicule of bone, or adhesion between the skull and the brain—cicatricial tissue—would be a cause for operation. It might happen after an injury that the portion of bone plainly depressed did not correspond with the center from which the convulsion started. In such a case one might expect to find

a fragment of the inner table pressing on the brain, or a blood-clot which had degenerated and become cystic, or adhesion, or what not; and the surgeon should always be guided in his operation by the study of cerebral localization and not of a gross depression of the skull, which he would easily recognize. It is perfectly possible for a depression in the skull to remain without trouble through life. The indication for an operation is to be sought for, when possible, by localizing the offending cause in some known cortical area. Operations for the cure of epilepsy, when of the Jacksonian type, are to be looked upon favorably unless the epileptic habit, from long continuance, has become established. In that case the prognosis is much more unfavorable. Shortly after the beginning of the trouble, however, trephining may be expected to have a good result. Where the lesion cannot be definitely located, where, in other words, the cause cannot be known, trephining for epilepsy has properly fallen into disuse. A careful study of that which has gone before in regard to locating lesions in the brain is to be considered, and the operation decided on or not, as the case may indicate. After a general convulsion local paralysis may remain; this is believed to be due to the exhaustion of some motor center in the cortex, and will probably correspond to that part of the body in which the convulsion began. If so, it will be an additional aid in locating the lesion. This will be true if the centers presiding over the special senses—sight, hearing, and speech—are involved.

CHAPTER XXV.

SURGERY OF THE SPINE.

SPRAIN.

THE spinal column may be sprained by the laceration to a greater or less degree of its ligaments, the result usually of extreme flexion, though violent twists and overextension, such as is produced by falling back over a bar, may give rise to the same form of injury. The most common situations for sprains are the cervical and dorsilumbar regions. Probably in all cases some tearing of neighboring muscles and fasciæ occurs, leading to effusion of blood, which is sometimes evidenced by a swelling or by discoloration of the skin. This is seen in the case of the rider who is thrown over his horse's head; the structures attached to the seventh cervical spine are torn through, and a hematoma, often very large, makes its appearance. In severe cases the anterior and posterior common ligaments may be lacerated. Injury to the ligaments which are in close proximity to the spinal canal may be associated with rupture of veins and hemorrhage into the canal. Laceration of the supraspinous ligament may be evident on examination, but with this exception we have to rely for diagnosis rather on the subjective symptoms and the history of the injury than on any obvious signs.

The **symptoms** are local pain, with aggravation on movement, tenderness, and rigidity. There may be some obvious swelling from extravasation of blood, but, owing to the depth of the parts sprained, this is generally absent. When the injury is in the lumbar region, there may be inability to move the legs or to start the acts of micturition and defecation, owing to the pain that these actions cause, and thus a lesion of the cord may be simulated. Sprains may be associated with hemorrhage into the canal, or complicated by the extension of inflammation to the spinal contents when the structures bordering the canal are affected. Neuralgia from involvement of the nerve-roots may give rise to long persistent trouble.

Treatment by rest and hot fomentations is the first essential. If, however, rest is prolonged unduly, muscular and fascial stiffness with accompanying pain will result, as in sprains elsewhere. It is well to avoid this in these cases by the early adoption of massage, since the patient is likely to attach an exaggerated importance to his spinal pain.

DISLOCATION.

Dislocation of the spine apart from fracture is rare, and is practically confined to the cervical spine, occurring most frequently in the lower half of this region. It may be either unilateral or bilateral.

The dislocation is usually brought about by hyperflexion, which causes the inferior articular processes of the vertebra above to slip forward and upward on the superior articular processes of the vertebra below. This is rendered possible by the tearing or separation of the intervertebral disk and laceration of the intervening ligaments. The displacement of the upper part of the spine is almost invariably forward (Fig. 407). Unilateral dislocation is sometimes brought about by extreme rotation of the neck. When this occurs, the head will be turned toward the opposite side and fixed in that position, while an irregularity in the spines and in the transverse processes will be obvious.

FIG. 407.—Dislocation forward of the sixth cervical vertebra (Guy's Hospital Museum).

Pressure upon the nerves issuing between the displaced vertebræ gives rise to peripheral pain and numbness. Varying degrees of paralysis, both of motion and sensation, up to the level of the lesion will result from compression of the spinal cord, and will depend upon the amount of injury inflicted. When the dislocation is unilateral, the cord may escape injury or the damage to it be but slight. Lesser degrees of displacement, not amounting to actual dislocation, may occur, as in one case which came under our notice, where laceration of ligaments led to undue mobility in the lower cervical spine. Three months after the accident, tingling in the fingers could be produced by forcibly exaggerating the normal movements of this part.

The **prognosis** depends upon the degree of damage to the spinal cord either produced directly or resulting from intraspinal hemorrhage.

Occipito-atloid dislocation, the result of violence, is always fatal, but recoveries after dislocation of the **atlo-axoid** articulation are on record. If after an injury the face is turned to one side and the power of rotation of the head is lost, a unilateral dislocation of this joint would be suspected. If the transverse ligament is torn, or the odontoid process broken, the case would in all probability be at once fatal.

Dorsal dislocation, if it ever occurs, could not be diagnosed from a fracture-dislocation at the same spot.

Treatment.—To begin with, reduction of the displacement should be attempted. This is much more likely to succeed when the dislocation is unilateral than when it is bilateral. It is usually recom-

mended that the reduction should be effected by combining extension with rotation of the head from side to side. It seems probable, as Walton points out, that it is rather to the manipulation involved in the rotation than to the extension that the success of this procedure is to be ascribed. He advocates, therefore, in cases of unilateral dislocation, the use of retrolateral flexion—that is, bending of the head obliquely backward and to the side opposite to that of the displaced process, in combination with rotation. He found experimentally that a moderate amount of traction in a direct line would not raise the displaced articular process in the least degree, whilst the above manipulation readily unlocked it.

In bilateral dislocation he recommends that the same method should be employed alternately on the two sides. Reduction will, however, often be found impossible. Taking into consideration the fact that death very speedily follows this displacement, if unreduced, we consider that the right line of practice to pursue is to cut down and expose the vertebræ from behind, dividing such structures as interfere with reduction, and, if necessary, removing the superior articular processes of the vertebra below.

FRACTURE; FRACTURE-DISLOCATION.

Fractures of the spinal column may be conveniently divided into those that involve the neural arch and its processes, and those that, passing through the bodies, interrupt the continuity of the spinal column. These latter are usually associated with more or less displacement of the upper part of the spine on the lower—a condition to which the name fracture-dislocation is given.

Fracture of the Neural Arch.—A *spinous process* may be fractured by direct violence; being superficial, the injury can be recognized by the ordinary signs of fracture—pain, mobility, crepitus, and irregularity in the line of the spines.

One or both *laminæ* may be fractured, with more or less displacement. Though this accident cannot always be recognized with certainty, a diagnosis may be effected by attention to the following points: A history of direct violence; lateral mobility of a spinous process; one or more spines out of the normal line or depressed below the level of those above and below; rarely, crepitus on manipulation; and, in some cases, symptoms pointing to compression of the cord.

The importance of diagnosing correctly this form of accident, more especially when associated with pressure upon the cord, depends on the fact that it offers more opportunities of hopeful surgical interference than are found in fracture-dislocation.

Fracture-dislocation.—Fractures of the vertebral bodies involving a complete separation of the spinal column are usually attended by displacement of the upper part of the spine on the lower. Fracture-dislocation is most common in the more flexible portions of the spine—*i. e.*, in the lower cervical and the dorsilumbar regions. It results most commonly from indirect violence, such as is caused by falls onto the head or buttocks, by a weight falling upon the shoulders, or by catching the head in passing under an arch. Under such circumstances the

injury is caused by acute flexion of the spine. One or perhaps two vertebral bodies are irregularly fractured, while, the arches being forcibly separated, either dislocation of the lateral joints takes place, or the neural arch and its processes are fractured. The upper segment is usually displaced forward and downward on the lower, owing to the line of fracture having commonly this direction. The same injury may result from direct violence, such as falling back over a bar. In these cases there occurs considerable comminution of the arches, whilst from the overextension produced the vertebræ are torn apart, in some cases at the junction of a body with its intervertebral disk. As the result of

FIG. 408.—Fracture of the first lumbar vertebra, with displacement forward of the upper segment of the spine (Guy's Hospital Museum).

the dislocation forward of the upper part of the spine on the lower, the cord is more or less severely nipped or completely crushed from the scissor-like action of the fragments.

All grades of severity are met with, but the extent of the injury has to be inferred rather from the history of the accident and the degree of paraplegia resulting, than from a local examination of the spine, which may, especially in muscular patients, show but little deformity, masked, too, as the latter is, by subcutaneous blood-effusion.

Symptoms.—There is generally severe local pain, and the patient has a marked dread of movement. He may volunteer the statement that his back is broken, and complain of loss of feeling in the parts

below. It might be supposed that collapse would be marked; but this is not the rule, and the alertness of the patient might suggest to the inexperienced that he had suffered no very severe accident.

Locally a boss may sometimes be felt, this being due to the prominence of the vertebra below the line of fracture, consequent on the forward displacement of the upper segment of the spine; or there may be a wide separation between two spinous processes, as though one vertebra had been rent from the other by hyperflexion. A spinous process may be broken off at its base or through the neural arch, and occasionally crepitus is felt as the patient is lifted. Accompanying the bone-injury will be much bruising and laceration of the soft parts, with swelling from extravasated blood, which renders an examination of the bones beneath difficult.

FIG. 409.—Fracture-dislocation, showing crushing of the cord (Guy's Hospital Museum).

Injury to the spinal cord is the most important result of fracture-dislocation (Fig. 409), and its severity is to be judged by the extent and severity of the paraplegia. Usually this is complete, the accident being followed by entire loss of movement and sensation in the parts below the level of the lesion. When partial, there is some hope that blood-extravasation and not bone-displacement is the cause of the paralysis. The reflexes are at first lost, and in some cases they remain permanently in abeyance. This, according to Bastian, indicates a complete transverse lesion of the cord, while their return indicates partial destruction only, and the retention of some power of conductivity. When the reflexes reappear, they are commonly exaggerated, and are associated with spastic rigidity of the muscles. If the cord is severely crushed, there will be complete loss both of sensation and of movement below the seat of injury; but in less severe degrees of compression the conduction of sensory impulses will usually be less interfered with than those of motion. In estimating the level of the lesion from the extent of the paraplegia, it should be remembered that the points of exit of the nerves from the canal do not coincide with their origin from the cord. A marked zone of hyperesthesia above the level of the paralyzed parts often exists. The bladder and rectum take part in the paralysis. Retention of urine, which is the rule in the first instance, soon gives place, unless relieved regularly by catheterism, to dribbling from overflow. When the lesion is above the lumbar center, owing to the fact that the reflex arc is intact, the urine is sometimes

voided periodically, though without the knowledge of the patient. Priapism is frequently present when the lumbar centers escape destruction. The temperature after the injury is usually considerably raised, reaching 106° F. or even a greater height; later it becomes subnormal, though it may be influenced by the various complications, such as cystitis, which subsequently arise.

Serious interference with breathing is caused by injury to the cord in the cervical and dorsal regions. A lesion above the fourth cervical nerve will cause death from total failure of respiration. Below this point respiration will be carried out by the diaphragm, owing to the escape of the phrenic nerves, and by a varying number of intercostal muscles, depending upon the level of the injury. In the lower dorsal region breathing may be hampered by paralysis of the abdominal muscles and tympanites. When the injury is in the lower cervical spine, contraction of the pupil often exists from damage to the ciliospinal center.

Prognosis.—This must be regarded as exceedingly grave, not only as regards immediate risks to life, but from the point of view of subsequent recovery. It depends upon the amount of damage to the spinal cord; and the higher up this is injured, the worse the prognosis. The cases that hold out the best chance of recovery are those in which the paraplegia is brought about by depression of a neural arch or by blood-extravasation. In fracture-dislocation the most hopeful cases are those in which the lesion occurs in the lumbar region below the termination of the cord. Death is commonly brought about by bronchitis when the movements of the chest are impeded, by bedsores, cystitis, and suppurative pyelonephritis.

Operative Treatment.—We have already referred to the fact that fracture of the neural arch is more likely to be benefited by an operation than fracture-dislocation. When the laminæ are broken by direct violence and driven in on to the cord, the case may be compared, as regards treatment, with depressed fracture of the skull. Laminectomy should be performed, and the depressed fragments elevated and removed. If this is promptly carried out, there is hope of complete relief, though the large amount of permanent damage that a comparatively slight lesion of the cord may cause should be borne in mind.

When, however, we have to deal with a fracture involving the continuity of the spinal column, the indications are less clear. Where marked displacement has occurred, and no doubt exists that the cord is irremediably crushed by the scissor-like action of the two segments of the spine, operation is not only useless but harmful, as adding to the immediate risks of life.

Certain cases remain in which the paralysis is partial, and the cord apparently not damaged beyond all hope of repair. It happens occasionally that the history of the onset and the character of the symptoms give strong reasons for supposing that the paralysis is caused not so much by the dislocation of the spine as by the effusion of blood into the membranes, or more rarely by a spicule of bone wounding the cord. Under these circumstances, operation for the relief of compression should be undertaken without delay. Such clear indications

are, however, rare, and more often it is impossible to state the exact nature of the lesion and to what extent the cord is irremediably injured. Two courses are open to us—either to operate in every instance, or not to operate at all unless some clear indication for so doing appears in the subsequent course of the case. Of the two, we prefer the former, and our practice is to perform laminectomy at once, regarding the operation in the first instance as an exploratory one. The hope of restoration of function in those cases in which the cord is not irretrievably damaged depends on the promptitude with which the cause of compression is removed; and however small the number of cases may be in which benefit is to be looked for, we hold that even these few justify one in immediate operation.

It is not difficult to perform laminectomy, since the soft parts are always found torn and detached from the bone, and the introduction of cutting instruments or forceps under the laminæ is easy from the displacement present. We advise the thorough irrigation of the wound after the operation and its immediate closure without a drain, so that there may be no need of the frequent dressings that drainage would entail.

Where an exploratory laminectomy has been undertaken in fracture-dislocation, and such displacement found that the removal of the neural arch does not suffice to relieve pressure on the cord entirely, the operation can be extended to the lateral processes, so that manipulation in the wound, combined with extension, may perhaps succeed in restoring the normal line of the spinal column.

Non-operative Treatment.—This begins with lifting the patient into bed, and requires six assistants, two below and two above, making extension and counterextension by the legs and shoulders, and two, one on either side, with hands clasped beneath the injured back.

When the first slight shock is over, however severe the case may appear, we advise, especially in dorsal fracture-dislocation, that powerful extension and counterextension be made, aided by the administration of an anesthetic, and the judicious manipulation of the spine by the surgeon at the same time. No harm can result from this, and though no benefit can be expected in those cases in which the cord has been completely crushed, the patient's suffering consequent on the irritation of nerve-roots is considerably alleviated. In those cases in which the paralysis is only partial, and in which reduction is preferred to operation as a means of treatment, such replacement of the fractured vertebræ may be an important factor in producing some amelioration of the paraplegia.

Often, however, attempts at restoration of the normal line of the spinal column fail from impaction and interlocking of the fragments of bone.

Rigid confinement in the supine position on a firm mattress must be enforced for five or six weeks, when, if the paraplegia has been but partial, the application of a support, such as a poroplastic or plaster-of-Paris jacket, will enable the patient to sit up, and shortly to be out of bed on crutches. He can thus be induced early to make all the use possible of his extremities, while at the same time his own efforts are aided by massage; and, indeed, we advise this latter in partial paraplegic cases as soon as the patient can bear the manipulation.

The use of a catheter and the treatment of cystitis will be guided entirely by the surgeon's experience. Not the least important factor in the prolongation of the patient's life is careful and skilful nursing, the nurse's special aim being the avoidance of bed-sores—a difficult matter, considering that the feces and urine are always passed involuntarily.

In fracture in the atlo-axoid region, if the patient survive, the same care must be taken to keep the head rigidly fixed (whilst the patient is recumbent on a firm bed) within the curve of a horseshoe sand-bag, a small firm pillow being placed under the nape of the neck. After a month one of the many forms of instrumental or felt supports should be fitted, which, by fixing the head and supporting its weight, will allow the patient to get up from his bed.

Fracture and Dislocation of the Coccyx.—*Dislocation* of the coccyx backward may occur during the act of defecation or during parturition. Displacement forward may result from blows or falls on the buttocks, though under these circumstances *fracture* is more frequently produced. Either condition can be easily diagnosed by combined internal and external examination; and reduction being effected by the fingers, the bowels must be kept confined for some days, the motions being subsequently rendered as soft as possible before the first action takes place.

Both these forms of injury, more especially fracture, as also mere contusions of the coccyx, may lead to a severe and chronic neuralgia known as *coccydynia*. It occurs generally in women, who from motives of delicacy will frequently refrain from mentioning it, and adopt semi-invalid ways. The pain is often so severe as to render sitting impossible, and any movement involving a strain on the part intensifies the suffering. The pain, though chiefly local, may extend up the spine, and in nervous people give rise to a dread of spinal disease.

An examination may reveal nothing but a tender spot on one or other surface or at the tip of the bone; in other cases evidence of dislocation or fracture may be found.

Treatment.—When nothing to account for the pain exists, subcutaneous division of the structures attached to the bone dorsally and laterally will sometimes produce a cure; but if not, or if there is known to be vicious union after fracture, with perhaps, as often happens, a painful projecting bony spicule, more or less of the coccyx should be resected. When dislocated, the bone may be replaced, if other means fail, by resection of the sacrococcygeal joint, aided by division of the surrounding fascial and muscular tissues.

HEMATORACHIS AND HEMATOMYELIA.

Hematorachis, or Spinal Meningeal Hemorrhage.—Hemorrhage into the membranes may accompany injuries of the spinal column, or may be the sole result of a blow or fall. The blood may be extravasated either within the dura mater or outside it, the latter being the more frequent.

The **symptoms** indicative of hematorachis are severe *pain in the spine*, extending some distance from the seat of injury, and dependent upon irritation of the meninges; *peripheral pain* in the distribution of

the nerves which have their origin within the area of the hemorrhage, due to the irritation of the sensory roots by the extravasated blood, the pain being paroxysmal and burning in character; *muscular spasm*, or occasionally persistent contraction, frequently associated with the latter, produced by irritation of the motor nerve-roots, and having a distribution that depends on the particular nerves affected. Opisthotonos may result from involvement of the vertebral muscles, and occasionally a general convulsive seizure may occur.

Following these symptoms, due to irritation of nerve-structures, *paraplegia* of varying degrees of severity, from pressure upon the cord, makes its appearance. There may be merely slight loss of power which quickly clears up, or the paralysis may be severe, though it is seldom complete.

The **prognosis,** unless the case is slight from the commencement, or amelioration of symptoms commences early, is unsatisfactory.

The **treatment** to commence with consists of absolute rest, the application of ice to the spine, free purgation, and the administration of sedatives when the pain demands it. When, however, marked pressure-symptoms exist, or when improvement does not show itself early, laminectomy is indicated. We do not see any reason for putting hematorachis on any other footing, as regards operation, than that on which surgeons have always placed intracranial meningeal hemorrhage. Relief can be afforded in most cases without opening the theca, as the hemorrhage is generally extradural; but if it is within the membranes, these should be incised and blood and clot washed out.

Hematomyelia.—Hemorrhage into the substance of the cord seems confined, as the result of injury, to the region of the fourth, fifth, and sixth cervical vertebræ, our experience in this respect coinciding with Thorburn's. The latter observer attributes this lesion to over-flexion of the spine, the usual form of injury to the lower cervical region. The most common forms of accident producing such acute flexion and consequent hematomyelia are falls and blows on the back of the head and neck, or forcible bending of the neck, as in passing under an arch.

The blood-extravasation is usually situated centrally in the gray matter, and varies in amount from small punctate hemorrhages to a collection which may extend from 1 to 2 inches in the gray substance. When large in amount, it may extend into the white matter, or even rupture into the membranes. It produces its effects either by destroying or compressing nerve-tissue (Thorburn). As the result of destruction of gray matter in the lower cervical region, paralysis with wasting of muscles and anesthesia occurs in the upper limb and in the muscles connecting it with the trunk. When the effusion is large enough to cause compression of the white columns, paraplegia varying in degree occurs in the parts below the level of the lesion.

When the cord is exposed for examination in fatal cases, the hemorrhage may sometimes be seen as a dark swelling, or may be perceived by the finger as a tense bulging; in other cases nothing whatever is obvious externally.

Symptoms.—Immediately after the injury the case may appear to be one of total transverse lesion from the completeness of the para-

plegia. The paralysis is recovered from to a greater or less extent in the lower limbs, leaving perhaps some slight weakness and rigidity of the legs, and is then practically confined to the upper extremities. Here more or less loss of power and wasting, depending for their distribution upon the extent of damage to the gray matter, remain permanently. When the effusion of blood is slighter in amount, and so produces less compression of the white columns, the paralysis is from the first mainly localized to the arms.

Occasionally the symptoms increase in severity for some hours after the injury, owing to the slow escape of blood. An extension of the paralysis at a later period will be due to myelitis. Much pain is complained of locally in the spine, occasionally shooting down the arms or around the chest. A rapid rise of temperature is sometimes seen, reaching 102°–104° F. in forty-eight hours; and extreme myosis from destruction of the ciliospinal center may also be present.

The **prognosis** as regards life in severe cases, and as regards ultimate recovery in all, must be guarded. Doubtless many of the less severe cases, which, if carefully studied, would reveal themselves as cases of hematomyelia, are ascribed to spinal concussion and sprain. While recovery from the results of compression of the white columns may be rapid and complete, there is usually left some permanent weakness and wasting in the upper limbs.

Treatment.—Beyond rest and appropriate medicinal treatment, there is none to be recommended. The punctate character of the hemorrhage and the difficulty of determining its exact position in many cases when the cord is exposed, and the fact that to reach it would inflict probably even greater injury on the nerve-tissues, render it unlikely that operation can ever be of any benefit.

CONCUSSION.

The question of spinal concussion is a vexed one. While some surgeons practically deny its existence, others class under that name conditions which are now known to bear a different interpretation. As in past years many paraplegic states were regarded as functional which we now, with improved methods of investigation, know to be the result of definite spinal lesions, so the generic term concussion is gradually becoming more and more limited in its application. By "concussion of the spine" is meant a more or less complete annihilation of the functions of the spinal cord, immediately consequent upon an injury, temporary in character, and unattended by any discoverable gross lesion.

The cases that have generally been considered as due to concussion are those of sprain of muscles and fasciæ, frequently seen in railway cases, the so-called "railway-spine," in which no cord-injury at all exists; or cases of hemorrhage into the cord and membranes. We can only speak of a case as one of concussion when all other known causes of paraplegia after injury have been excluded. Even then the term must be regarded as provisional, for, after all, the idea that a molecular disturbance of nerve-matter constitutes concussion is only a good working hypothesis.

The *a priori* arguments against the likelihood of spinal concussion are founded upon the well-known anatomical relations of the spinal cord; notably its small size as compared with the diameter of the spinal canal, and the way it is suspended with lateral support from the denticulate ligaments and the spinal nerve-roots themselves. As, however, we know that hemorrhage, the result of an injury, may take place into the cord without any obvious lesion of the spinal column, there need be no difficulty in assuming that slighter forms of injury may lead to some disturbance of the cord short of obvious structural defects—that is, to concussion.

While we believe spinal concussion to be rare, we see no other way of explaining those cases, occasionally met with in the accident-wards of a large hospital, which after a fall present evidence of more or less paralysis and anesthesia or impairment of cord-function, and which within a week or less have complete recovery of power and sensation. It is true that hemorrhage into the spinal cord or canal might possibly be the cause, though the early recovery and the absence of characteristic symptoms render it unlikely.

In hematomyelia resulting from injury the hemorrhage appears to be almost invariably confined to the lower cervical region, and the destruction of gray matter causes paralysis of certain muscles of the upper extremities, while the legs, which generally present more or less paraplegia, recover much more rapidly and completely than the arms, in which some permanent weakness and wasting remains. In hemorrhage into the membranes the characteristic symptoms produced by irritation and compression of nerve-structures usually suffice to distinguish these cases from mere concussion.

In concussion the arms never present localized paralyses, such as result from hemorrhage into the cord; nor do we ever find peripheral pain or muscular cramp, such as occurs in hematorachis. In view of the above facts, paralysis picking out a few muscles, or spasm or pain in the distribution of certain spinal nerves, must be held to exclude concussion.

Symptoms.—A very few cases have been recorded in which the paraplegia, complete from the first, has terminated in death. Such cases are open to considerable doubt as regards the diagnosis, though we are unable to give any other explanation than that of concussion to the case we describe below. Such cases would, during life, be almost certainly diagnosed as hematomyelia or some other lesion of the cord.

The more characteristic cases present incomplete loss of power and sensation, the paraplegia being usually confined to the legs, though some cases may also have some weakness of the arms, most noticeable in the grasp. Usually the bladder and rectum are also affected. The loss of power and sensation is in the slighter cases most marked in the feet and toes, and gradually diminishes as the trunk is approached. One must be careful not to mistake for concussion those cases of sprained spine in which an inability to move the legs exists, on account of the pain caused by such attempts. In the latter cases it will be found that this supposed paralysis is a difficulty in raising the weight of the leg from the bed, movements being otherwise unimpaired, while in the former such inability would be attended with paralysis of the

whole limb. No spasm of muscles occurs, nor is there any peripheral pain. All the symptoms pass off frequently within forty-eight hours, or at latest within a week.

The case of complete paraplegia referred to above as one of concussion was under the care of one of the writers in Guy's Hospital in 1894. A woman aged fifty-nine fell down stairs on to her back, and when picked up was found to be paraplegic. No special investigation of the case was possible for some hours. It was then noticed that there was complete loss of power from the neck downward, with paralysis of the bladder; the breathing was carried out by the diaphragm. At first reflexes could be obtained, but were soon lost. There was anesthesia below the level of the umbilicus. On the second day the temperature was 103.5° F., and on the tenth she died from pneumonia. A minute post-mortem examination was made, but nothing was found to explain the symptoms, both brain and cord being to all appearances perfectly healthy. But for the autopsy the case might have been explained as one of hemorrhage into the cord in the cervical region.

Treatment.—Beyond rest and such drugs as occasion might suggest, there is nothing to be done.

LAMINECTOMY.

Laminectomy is the operation for exposing the spinal cord and its membranes by the removal of more or less of the neural arches. It is indicated when pressure-symptoms have appeared as the result of compression by inflammatory products, blood, bone-displacement, and tumors of the spinal cord and membranes.

As usually performed, a median vertical incision is made through the skin over the affected area; but, as has elsewhere been pointed out, it is far better to make a bold horseshoe incision so as to throw an integumentary flap either upward or downward. The advantage is that there is no surface-wound over the spinous processes, since the curve of the "horseshoe" crosses the spine between two of the processes, and thus neither wound nor scar is pressed on as the patient lies in bed. The muscles are detached by a vertical incision on each side of the spines, and, the neural arch being exposed, a lamina is divided by a Hey's saw or by cutting-forceps, one blade of the latter being inserted beneath its lower margin. This is difficult except in those cases in which the operation is undertaken for fracture, and an alternative is to apply a large trephine on the neural arch, the pin of the trephine working in the stump of a spinous process which has been previously cut off. By this means a part of the lamina of each side, with the root of the spinous process, can be removed. Further exposure of the spinal canal is readily accomplished by means of Hoffmann's or Horsley's special cutting-forceps. The theca is now exposed; if healthy, it will have over it a variable amount of fat and large veins; but in cases of caries of the spine it is likely to present a thickened, leather-like appearance, with chronic inflammatory deposits around it. On incising the fat over the dura mater, hemorrhage from the veins in it may for the moment be sharp, but is controlled by pressure. The spinal cord is now exposed, when necessary, by a vertical

incision through the dura mater, and cerebrospinal fluid freely escapes. Further stages in the operation must be regulated by the exigencies of each case. The dura mater should only be opened when necessitated by the existence of the lesion within the membranes, and should especially be avoided in tuberculous cases on account of the risk of setting up a tuberculous meningitis. If the operation has been merely exploratory, and nothing abnormal found, the wound may be immediately sutured without any provision for drainage; and if the neural arch has been removed with care, more especially if it has been partially detached, so that it can be raised as on a hinge, the bones also may be replaced. When an infective condition is met with, the surgeon's general experience must guide him as to whether to leave a drain in the wound or not, though careful cleansing will enable him to dispense with it in many cases. When the dura mater has been incised, drainage of the subdural space should be effected, when found necessary, by a capillary drain, such as horse-hair, and not by a rubber tube.

SPINA BIFIDA.

This term is generally used to denote a congenital malformation of the vertebral column in which one or more of the arches have failed to close, and the contents of the spinal canal protrude in the form of a fluid tumor. Not all forms of spina bifida are included in this definition, for in some cases, though the laminæ are deficient, there is no protrusion.

To understand the nature of these malformations, the development of the cord must be borne in mind. The primitive neural canal is formed by the coalescence along the median line of the medullary folds, two ridges derived from the epiblast. In this way a hollow tube is formed, which eventually becomes separated from the surface epiblast on which it originated by the ingrowth of mesoblast, which forms the bones, meninges, and muscles. The epiblastic tube thus encircled is the spinal cord.

Varieties of Spina Bifida.—These may be grouped under five headings, according to the stage at which arrest in development takes place: 1. Myelocele; 2. Meningomyelocele; 3. Syringomyelocele; 4. Meningocele; 5. Spina bifida occulta.

Myelocele.—In this malformation the medullary folds have failed to coalesce, generally to a limited extent at the caudal extremity, so that the central canal of the cord opens on to the surface of the body in the lumbar region. The unclosed portion of the cord is represented in the lumbosacral region as a bright-red vascular area resembling nevoid tissue. In a specimen in Guy's Hospital Museum this area is of a lozenge shape. It usually presents a median longitudinal furrow, which represents the primitive medullary groove, and which is continuous above with the central canal of the cord. Microscopically it is found to be composed of nerve-cells, neuroglia, and nerve-fibers interspersed with a plexus of arterioles, venules, and capillaries (Sutton). Arrest of development or asymmetry of the spinal column is often associated with myelocele, and ectopia vesicæ often co-exists.

Meningomyelocele.—In this variety the deficiency in the arches is associated with protrusion of the spinal cord and membranes. The sac-wall is composed of skin and dura mater, and is lined by the arachnoid membrane, its cavity being continuous with the subarachnoid space. The spinal cord leaves the canal and crosses the sac to the posterior wall, in which it is continued as a flattened layer of nerve-tissue still retaining its central canal. From this expansion the nerve-roots arise and cross the sac to their respective intervertebral foramina. The anterior and posterior roots are often distinct and separated by a continuation of the ligamentum denticulatum. It is the most common variety of spina bifida, forming 63.2 per cent. of all cases examined by the Clinical Society of London. This form is due to a failure in the development and ingrowth of the mesoblast that normally separates the medullary tube and epiblast, these two structures consequently remaining in close relationship. That the medullary plates have coalesced is shown by the presence of a central canal in the flattened cord.

FIG. 410.—Spina bifida (meningomyelocele), showing cord and nerves crossing sac (Guy's Hospital Museum).

Syringomyelocele.—This originates in the same way as the preceding form, from defective ingrowth of mesoblast. The protrusion contains the spinal cord and membranes, but the cavity of the sac is formed by the dilatation of the central canal of the cord. The nerves consequently do not cross the cavity, but pass forward to the foramina round the outer surface of the expanded cord. This form is extremely rare. According to De Ruyter, it is invariably situated laterally. Arrests of development in other parts, such as ectopia vesicæ and genital fissure, are common.

Meningocele.—Here the membranes alone protrude, the cord occupying its normal position in the spinal canal. The deficiency in the arches is usually limited to a small extent. Very rarely the protrusion takes place between two adjacent arches or from the hiatus sacralis. The cavity is lined by the arachnoid membrane. Meningocele has a tendency to become pedunculated, and in some cases the aperture of communication may be occluded. According to the Clinical Society's Committee, it forms 8 per cent. of all cases.

Spina Bifida Occulta.—This form is characterized by a vertebral cleft without any protrusion of cord or membranes. Associated usually with this malformation is an abnormal growth of hair, which may be localized over the defective arches, or may have a wider distribution over the loins and buttocks. This hypertrichosis may exist at birth or may develop at puberty. In many cases this is the only symptom of spina bifida occulta. Attention is, however, often drawn to the spinal malformation by the presence of anesthesia, club-foot, perforating

ulcers, and other trophic changes of the lower extremities. These are apparently brought about by pressure from local hypertrophy of the cutaneous and subjacent soft parts. In the limbs examined there has been found a thickening of the vessel-walls, especially affecting the muscular layer, and also in some cases degenerative changes in the nerves.

Clinical History.—**Myelocele** is incompatible with life for more than a few days, owing to the continual leakage of cerebrospinal fluid.

In those forms (**meningocele, meningomyelocele, syringomyelocele**) in which the cleft is associated with protrusion of the spinal contents, the swelling varies in size at birth from a hazel-nut to a small orange. It is rounded or oval in shape, occasionally lobulated from the presence of septa, and generally median in position, though it may deviate a little to one side. As a rule sessile, with a slight constriction at the base, in rare cases it may be pedunculated. Meningomyelocele may present a median longitudinal furrow corresponding to the attachment of the cord, or a dimple (the so-called umbilicus) at the summit where the cord meets the sac-wall. Both dimple and furrow are by no means constant, and depend to some extent upon the distention of the sac. In consistence the tumor is sometimes soft, sometimes firm and elastic, and the tension is increased by coughing or crying. Fluctuation, which is always obtainable in the fluid tumor, may be obtained, where hydrocephalus co-exists, between the sac and the fontanels. The deficiency in the arches may often be felt when the sac is lax. Normal skin but seldom exists over the whole tumor; in most instances it extends up for a variable distance from the base, the rest of the covering being composed of a thin bluish membranous tissue. It is not uncommonly ulcerated, or even gangrenous on the surface, and in some cases may present patches of nevoid tissue.

Any portion of the spine may be affected, but the most common situation is the lumbosacral region. The general health may be good and the functions intact. On the other hand, when the spinal cord is involved there may be paralysis of the bladder, rectum, and lower limbs, and associated with this last-named talipes, most commonly calcaneus. Trophic changes, such as perforating ulcer, may also occur. An important complication is hydrocephalus. This may be present at birth or may develop later, and in a few cases has been noted as supervening after the cure of the spina bifida by artificial means.

The majority of cases of spina bifida die if left to themselves, this being due in a large proportion of cases to marasmus. A fatal termination may result from rupture of the sac with consequent leakage of the cerebrospinal fluid; from meningitis following inflammation of the sac; or from the troubles dependent on paralysis.

Diagnosis.—From the point of view of operative interference, it is important that diagnosis should be made, if possible, between meningocele and meningomyelocele. Attention should be directed to the following points distinguishing meningomyelocele: 1. The larger size of the deficiency in the arches; 2. Umbilication and furrowing of the sac; 3. The presence of paralysis and club-foot. Transparency of the sac cannot be relied upon as a means of distinguishing between the two forms, for some sacs, though containing cord and nerves, are

found to be quite translucent. A higher situation in the spine or the presence of a pedicle will point to meningocele.

Treatment.—In those cases in which operative measures are not justifiable, treatment will be limited to protecting the sac from injury. If the surface is ulcerated or gangrenous, some dry antiseptic dressing must be applied. Parker recommends painting with iodoform and collodion in cases in which the wall is very thin. Practically the only operative measures employed are the injection of iodin and excision of the sac. Treatment by repeated tappings is but seldom resorted to on account of the attendant dangers, while ligature of the base must be regarded as unjustifiable from the impossibility of determining with certainty the absence of nervous elements in the sac.

Injection with Iodin.—This method, which aims at bringing about a cure by the production of a localized adhesive inflammation, has met with a considerable amount of success. Morton's fluid, which is used, consists of iodin gr. x, potassium iodid gr. xxx, glycerin ℥j. The puncture should be made through healthy skin at the base of the tumor, to avoid risk of injury to the spinal cord when incorporated with the sac. It is not necessary in most cases to withdraw any fluid from the sac previous to injection. From $\frac{1}{2}$ to 2 drams of Morton's fluid are injected, and the site of puncture sealed with collodion. The cases for treatment should be carefully selected. Injection should be postponed until the child is at least two months old, unless the sac is threatening to burst. Paralysis and talipes will not be benefited by the treatment, and as contraindications may be mentioned hydrocephalus and marasmus. The dangers of the operation are shock, convulsions, meningitis, paralysis, and the subsequent appearance of hydrocephalus.

Excision.—In common with many surgeons, we think there is less risk involved in incising the sac than in injecting it, and that the likelihood of damaging the spinal cord and nerves, when these are contained in the tumor, is less in the former mode of treatment. The contraindications are the same as those for injection, and the cases should be as carefully selected. The main risk of this operation is from leakage of the cerebrospinal fluid.

Operation (Mayo-Robson).—An incision is made through the skin on each side of the tumor, about half an inch from the base, marking out two flaps, which are carefully dissected off the meninges. The membranes are then punctured to let out the fluid, and then pared away so as to leave two flaps, one rather longer than the other ($\frac{3}{4}$ inch and $\frac{1}{2}$ inch), so that the lines of union of the meninges and skin-flaps are not superimposed. The pairs of flaps are then sutured separately and closely to avoid risk of leakage of the cerebrospinal fluid. Where skin-flaps are not obtainable from the base of the tumor, they may be obtained by dissecting up the skin from the loins sufficiently to allow of the flaps being slid inward toward the middle line. When the cord is incorporated with the sac, a careful incisions hould be made into the sac, after the skin-flaps have been fashioned, to determine the position of the cord and nerves. Redundant sac should then be cut away, care being taken not to injure nerve-structures, and, the cord being replaced in the spinal canal, the meningeal and skin-flaps are closely sutured over it.

CONGENITAL SACROCOCCYGEAL TUMORS.

Parasitic Tumors (Teratomata) originating in a Duplication of the Embryonic Area.—These may be regarded as the lowest grade of a series, the highest expression of which is the rare malformation known as "conjoined twins." They occur as irregular pendulous tumors attached to the coccygeal region, sometimes of large size at birth, sometimes increasing in size subsequently, and bearing no resemblance to the body or limbs of a fetus. They differ from ordinary tumors in the great variety of tissues of which they are composed. In one class rudiments of the skeleton and of the different viscera are found; in another the tissues present nothing suggestive of any special organ. While the former are to be regarded as remnants of a parasitic fetus which has failed to develop, in the latter there is some doubt as to whether the tumor is to be considered as parasitic or as due to a developmental defect in a single individual.

Cystic Tumors originating between Rectum and Sacrum.—The majority of these tumors have their origin in persistent remnants of the postanal gut and neurenteric canal. They may be either multilocular or unilocular. The former give rise to large tumors, often pedunculated. They are made up of a number of cysts, varying in size from a millet seed to a cherry, which are lined with cylindrical, cuboid, or flattened epithelium, and which contain a thick, mucoid fluid.

Unilocular cysts having a wall similar in structure to that of the intestine, and found lying between the rectum and sacrum, have been met with. A cyst of this kind, which projected into the rectum as a polypoid tumor the size of a hen's egg, has been described. It was readily shelled out by incising the rectal wall lying over it.

Dermoids also occur in this situation, and may attain a very large size, one weighing as much as 14½ pounds having been described.

Cystic Tumors originating outside the Sacrum and Coccyx.—Cysts in this region are usually sequestration dermoids arising along the line of coalescence of the dorsal folds. The possibility of a cystic tumor over the lower end of the sacrum being a spina bifida should be borne in mind. Cases of meningocele projecting from the hiatus sacralis as a pedunculated tumor have been reported.

Allied to the dermoids are the dimples and sinuses found over the coccygeal region. They are usually regarded as resulting from imperfect coalescence of the dorsal folds, though according to another view they are vestiges of the neural canal. The sinuses usually open opposite the tip of the coccyx, and run upward for as much as two inches in some cases. They appear to be lined with skin, and in some cases hair is found growing from the wall.

ACUTE OSTEOMYELITIS OF THE VERTEBRAE.

Acute osteomyelitis of the spinal column, though rarely met with, derives a special importance from the close proximity and liability to infection of the spinal cord and membranes. It is about twice as frequent in males as in females, and though liable to make its appearance any time during the period of growth of the skeleton, it occurs most

often between the ages of ten and fifteen. The disease has its primary seat in the lumbar vertebræ in about half the recorded cases, and the initial focus of inflammation is as often in some portion of the neural arch as in the body. Suppuration occurs in every case, though to a varying extent. Tenderness and rigidity of the affected portion of the spine are the first symptoms, followed in three or four days, in those cases in which the arch is affected, by inflammatory swelling. When the bodies are the primary seat, the abscess will form in front of the spinal column and will be later in making itself evident. Curvature is noted but rarely, mainly owing to the fact that the patient at once assumes the supine position.

The special danger is the spread of inflammation to the contents of the spinal canal, meningitis or meningomyelitis occurring in about half the cases, with an almost invariably fatal result. Death, which occurs in about three-quarters of the cases, is either brought about in this way or by general infection. Primary disease of the neural arch is a more favorable condition than that of the body, owing to the earlier recognition of the disease in the former and the greater ease with which abscesses can be drained and sequestra removed.

The **treatment** should be conducted on the same lines as for osteomyelitis elsewhere.

CARIES OF THE SPINE (POTT'S DISEASE).

Definition.—By caries of the spine is meant an inflammatory process characterized by rarefaction and absorption of the vertebræ, leading in most cases to angular curvature. It follows the same course as caries elsewhere, but derives its special characteristics from its situation.

Etiology.—The most common cause is *tubercle*. This is known not only by the clinical course run by the disease, but by the presence in the affected parts of the tubercle bacillus, and the characteristic changes in the tissues that it produces. Caries, though rarely due to *syphilis*, is met with as the result of both the congenital and acquired forms of disease, but is more commonly observed in the latter. The cervical region is most frequently affected. Its diagnosis will depend, as a rule, upon the co-existence of other lesions pointing to syphilis, which are usually well marked. As a factor in causation *injury* must in the main be regarded as one of predisposition. Its importance in this respect is shown not only by the definite history of injury so frequently obtainable, but by the partiality of caries for such situations as most readily lend themselves in childhood to damage. Whether it may at times be the sole agent in bringing about the characteristic deformity is questionable. The cases that bear this interpretation quickly recover without suppuration, and the co-existence of tubercle cannot be determined. Whatever share trauma may have played in originating the disease, there can be no doubt of its importance as a factor in perpetuating the caries, when once established, in those cases in which the superincumbent weight of the body is not relieved by efficient means.

Both sexes are said to be equally affected by Pott's disease, though

our figures show 25 per cent. more males than females. Whilst the onset is most common in childhood, the disease is still frequent up to sixteen years of age. It is met with later in life, though rarely. We have known it to commence and run a typical course at seventy years of age.

Pathology.—*Site of Onset.*—Tuberculous caries generally originates in the soft growing bone between the body of a vertebra and its upper or lower epiphyseal plate, and not in the epiphysis itself. It may be compared in this respect to the manner in which similar disease starts in the long bones between the shaft and the epiphysis. Occasionally the primary seat may be on the surface of a vertebra, more often on its front and sides than on its posterior surface; or at other times in the cancellous tissue of the bodies. Caries commencing in the laminæ and transverse processes is decidedly rare. Some of the cases and specimens recorded as such are instances of acute osteomyelitis, and not of tuberculous disease. If we except the atlo-occipital, atlo-axoid, and sacrococcygeal joints, we may regard the synovial joints of the spine as not liable to primary tuberculous infection. In these three situations the starting-point of the disease is either in the synovial membrane or in those parts of the bones that enter into the articulation. In atlo-axoid disease the odontoid process is frequently affected, and very great danger of the atlas slipping forward on the axis exists. In caries of the sacrum the process starts most often in the lumbosacral region, though the bone is occasionally invaded from the sacro-iliac joint.

The following is the order in frequency with which in our experience the different regions of the spine are affected: Dorsilumbar, middorsal, lower lumbar, midcervical, cervicodorsal, atlo- and occipito-axoid. Necrosis is at times present as well as caries, and fairly large sequestra may be thrown off.

FIG. 411.—Caries of lumbar vertebræ. The two wedge-shaped portions correspond to the bodies of the first and second lumbar vertebræ. The vertebræ above and below have fallen together, and almost meet anteriorly (Guy's Hospital Museum).

Course.—From the initial focus the disease spreads to the neighboring parts, leading in most cases to the destruction of the bodies of one or more vertebræ with their intervertebral disks and ligaments. This may be contrasted with the absorption brought about by the

presence of aneurysm, in which case the intervertebral disks remain, though the bodies above and below are destroyed. The process is more rapid in the soft, rapidly growing vertebræ of young children than in adults. When caseation of the inflammatory products takes place before the enclosed bone is absorbed, sequestra result. These are generally soft and friable in children, though firmer in adults.

More rarely the disease is widely diffused, assuming the form of a superficial erosion which affects the front and sides of the vertebræ, often over a considerable extent of the spine. Less frequently the posterior surface of the bodies is affected in this way. The bodies are not completely destroyed, as in the preceding form, and so no deformity occurs. The bone is irregularly eroded, and is sometimes so riddled by the carious process as to assume a worm-eaten or honeycombed aspect (Fig. 413).

FIG. 412.—Caries of posterior surface of the fourth and fifth cervical vertebræ; caseous mass in the canal, which compressed the cord and caused fatal paraplegia (Guy's Hospital Museum).

FIG. 413.—Diffuse form of caries, giving a honeycombed appearance to the vertebræ (Guy's Hospital Museum).

Angular Curvature.—When the body of a vertebra disappears, its spine projects unduly, owing to the sharp angle produced by the settling down of the vertebræ above on those below (Fig. 414). In this way the characteristic boss is produced, its size depending upon the extent of bone-destruction. Deformity occurs most readily in the dorsal region, owing to the normal convex curve backward of this

part. In the midcervical and lumbar regions a boss is later in making its appearance, as the natural concavities must first be obliterated. In the lumbar region, moreover, the vertebræ are larger and firmer and less likely to yield.

Compression of the Spinal Cord.—Narrowing of the spinal canal sufficient to cause compression of the cord but rarely occurs as the

FIG. 414.—Extreme angular curvature due to destruction of the five upper dorsal vertebræ (Guy's Hospital Museum).

direct result of angular deformity, even when this is extensive. When symptoms of paralysis appear, it will be found that these are due in the majority of cases to the accumulation of inflammatory products, granulation-tissue, caseous material, or pus between the bone and the dura mater. This is accompanied in some cases by a thickening of the dura mater.

Pressure on the cord may in rare instances be due to displacement produced by fracture through a carious vertebra (fracture-dislocation), to the sudden bursting of an abscess, to hemorrhage, or to the protrusion of a sequestrum into the canal. As regards the effect of pressure on the cord, Gowers, following Charcot, states that in all cases myelitis occurs at the seat of compression. Thorburn and others, however, maintain that pressure may lead

to paraplegia by causing either anemia and subsequent degeneration of the cord or edema from compression of the extramedullary veins and lymphatics. These changes in the cord are followed by descending degeneration in the lateral columns. When compression-paraplegia occurs, the disease is found to be seated in the great majority of cases above the sixth dorsal vertebra.

In atlo-axoid disease the canal may be narrowed by the gradual sliding forward of the atlas upon the axis, the posterior arch of the atlas gradually approaching the odontoid process.

Suppuration.—Abscess makes itself evident in about 25 per cent of all cases affected with spinal caries. Although in the majority there is no obvious suppuration, our failure clinically to detect pus does not preclude the possibility of its existence. It is probably much more frequent than the above figures indicate. Collections of pus, as elsewhere in connection with tuberculous disease, may dry up when deeply seated, especially in the thoracic region; or the pus may make its way into some hollow viscus and be discharged without detection. The absence of evident suppuration does not argue in favor of the carious destruction being slight: some of the most deformed patients have never had an abscess. It occurs more commonly in connection with superficial caries, and becomes evident earlier in these cases.

Repair.—When recovery takes place, repair is brought about by bony ankylosis of the bodies above and below the seat of disease. The spine is further strengthened by buttresses of bone thrown out in front of the bodies of the vertebræ, and often by bony fusion of the arches behind.

General pathological changes, such as cachexia, lardaceous disease, or a sudden outbreak of acute tuberculosis, may be seen as in other chronic tuberculous affections.

Symptoms.—It is of importance that spinal caries should be diagnosed, when possible, before the development of angular curvature; though when the early symptoms have been slight, the patient may not seek advice till aware of a projection of the spine.

Pain, though variable in intensity, is present in most cases either at the site of the disease in the spine or referred to a distance along the course of the nerves which arise at the level of the mischief. Local pain is, as a rule, moderate, the patient complaining commonly of general backache or weakness, but in acute cases it may be very severe. In these cases it is often accompanied by a marked elevation of surface-temperature and by hyperesthesia, especially to heat and cold. Pain in the back may not be felt until elicited by direct pressure upon the spinous processes or by bearing downward upon the head and shoulders. It is aggravated by movement and by the communication to the spine of such jars as are experienced by riding in a public vehicle, stepping down sharply on to the heels, or taking a false step, and even in coughing and sneezing. Pain of a neuralgic character is often felt in the distribution of the nerves the roots of which are irritated or compressed at the seat of inflammation. Thus, in atlo-axoid disease pain is referred to the occipital region; in cervicodorsal and lumbar caries, to the arms and legs respectively. When the dorsal region is affected, intercostal neuralgia is complained of, or pain referred to the pit of the stomach and interpreted as "stomach-ache" by children. The so-called "girdle pain," or sense of constriction, is sometimes met with in adults.

Hyperesthesia over the affected region can sometimes be made out. In doubtful cases it is not a symptom upon which much reliance can be placed, as it is often well marked in cases of neurotic spine. Herpes zoster is in rare instances met with.

Rigidity of the spine is the most valuable of all the signs of Pott's disease. The patient loses in the affected region the natural flexibility of the spine, moving the back rigidly as a whole when asked to bend over. If the hand be placed on the erector spinæ on either side of the diseased area, the muscle will be found to be firm and contracted, and this may be obvious as a distinct fulness. Though exaggerated when stooping, this contraction is always present, and will disappear only when repair has taken place. The fixed and rigid position in which the back is held leads to very characteristic movements on the part of the patient. When stooping, he will rest one hand on his thigh or on a piece of furniture, or will cautiously lower himself into a squatting attitude by flexing his hips, knees, and ankles, keeping the back as stiff and upright as possible. An adult with dorsal caries will cease to move those ribs that correspond to the seat of disease, and he may eventually adopt an entirely diaphragmatic respiration.

Deformity.—The presence of a marked angular curvature (Pott's boss) is pathognomonic, but the diagnosis has frequently to be made without its aid. In cases unattended by pain it may be the first symptom to call attention to the caries. Although occurring at some period of the disease in the majority of instances, those cases in which the disease assumes a diffuse form are unattended from first to last by deformity. It has already been pointed out that an obvious projection will result from a slighter degree of mischief in the dorsal region than elsewhere, owing to the arrangement of the normal curves of the spine. In rare cases some lateral deviation of the spine may be noted as an early symptom, disappearing as the caries progresses. It is likely to lead to an error in diagnosis, and careful attention should consequently be paid to the other signs of disease present.

Compared with other symptoms, the *temperature* is of little value, for even in acute uncomplicated cases it may not reach 100° F.; and as the majority are of a chronic type, slight variations of temperature within the limits of 1° F. will not aid the diagnosis.

Atlo-axoid Disease.—Stiff neck with loss of the power of rotation of the head, local tenderness, and often more or less wry-neck are early symptoms of the disease. The aggravation of the pain caused by any movement leads children to support the head by steadying it with both hands or by resting the chin on some projecting ledge of furniture, though they will also do this in cervical disease lower down. Pain in the course of the great occipital nerve is sometimes complained of. In disease in this part, or in the upper cervical region generally, the position downward and forward in which the chin is carried impedes the entry of air and gives rise to the characteristic grunt. Examination shows a variable amount of deep thickening with muscular rigidity. When displacement forward of the atlas, carrying with it the head, takes place, a prominence is noticeable behind, due to the spine of the axis, and between this and the occiput a sulcus. In unilateral disease the atlas slides forward on one side only, and the chin consequently points downward and to the side opposite the lesion. The forward move-

ment of the atlas on the axis may lead to the compression of the cord between the odontoid process and the arch of the atlas. If this displacement takes place suddenly, immediate death results. Postpharyngeal abscess, which often forms in connection with disease in this region, is considered elsewhere.

Occipito-atloid disease is less common than the preceding. The symptoms are in the main similar to those just described, together with the loss of the power to nod—the characteristic action of this joint.

Sacrococcygeal disease begins not uncommonly in the synovial joint. Local pain, increased on defecation, with an inability to sit down, will draw attention to it. Its recognition requires no special description.

Abscess.—The course of abscesses in connection with spinal caries is determined by the anatomical arrangement of muscles and fasciæ, and they derive their nomenclature from the route taken by them or from the situation in which they become evident rather than from the region in which they originate. They are most often met with in connection with lumbar caries, becoming relatively less common the higher the site of disease in the spinal column.

Cervical Region.—Postpharyngeal abscess arises in connection with the upper cervical region, and is especially a sequel of atlo-axoid disease. It may be confined to the region behind the pharynx, and pushing the posterior wall of this forward gives rise to difficulty in breathing and swallowing. It is readily detected in this situation as a fluctuating swelling. In other cases it may be directed to the side of the neck by the prevertebral fascia, and point in front of the sternomastoid muscle. Rarely it travels down into the posterior mediastinum. If it is allowed to burst into the pharynx, death may occur from suffocation—an accident likely also to attend the unskilful opening of the abscess in this situation.

Postesophageal abscess arises in connection with the lower cervical vertebræ; it may cause both dyspnea and dysphagia from compression. In a case under the care of one of the writers, after producing pressure-symptoms it appeared as a deep-seated swelling beneath the lower attachment of the left sternomastoid.

Dorsal Region.—As the result of dorsal caries it is uncommon to find an abscess pointing posteriorly in the thoracic region (dorsal abscess). When suppuration makes itself evident in this situation, the pus makes its way between the vertebral ends of the ribs, following the course of the posterior branches of the intervertebral arteries to the back. It may extend forward beneath the pleura and point at the side of the thorax, or, passing upward from the upper dorsal vertebræ, appear at the root of the neck. In the lower dorsal region the abscess more often tracks down beneath the ligamentum arcuatum internum, and, entering the sheath of the psoas muscle, gives rise to a *psoas abscess.*

Lumbar Region.—Pus arising from disease in this situation may burrow through the layers of the lumbar fascia and point in the loin (*lumbar abscess*); it may make its way down in front of the fascia covering the psoas muscle, to form a swelling in the iliac fossa (*iliac abscess*); or, gravitating into the pelvis, it may escape through the sacrosciatic foramen, giving rise to a *gluteal abscess.* More commonly it gives rise to an *iliopsoas abscess.* The pus, entering the sheath of the psoas mus-

cle, follows the course of that muscle to the iliac fossa, where it may give rise to a large swelling which is limited by the attachments of the iliac fascia. From this situation it enters the thigh beneath Poupart's ligament by a narrow neck external to the femoral vessels, and, continuing its course, makes its way beneath the femoral vessels and along the profunda artery to the upper and inner part of the thigh. Here it will usually give rise to a large swelling if left to itself, and subsequently burst. At an early stage careful palpation of the abdomen may reveal a sausage-shaped swelling in the course of the psoas muscle, somewhat tender, and too deeply situated to yield definite fluctuation. It may be detected in this way when scarcely thicker than a finger. When the abscess has reached the thigh, fluctuation is readily detected between the swelling below and that above Poupart's ligament. Pus may simultaneously make its way into the loin and point there as a lumbar abscess. A psoas abscess may rarely open into the hip-joint as it passes in front of it in the thigh. It is occasionally bilateral, especially in connection with lumbosacral caries. Attention may be drawn to the presence of abscess by cruralgia and inability to straighten the thigh. It must be remembered that psoas abscess may run its course without any interference with the hip-movements and without subjective symptoms, and may thus simulate hip-joint disease, from which it must be distinguished by careful attention to the other symptoms present.

Pressure upon Nerve-roots.—The results of the compression and irritation of sensory nerve-roots in the production of peripheral pain have already been referred to. This is frequently accompanied by hyperesthesia of the skin, and later, when the conducting power of the nerves is impaired, by anesthesia. Muscular weakness due to compression of the motor nerve-roots is not, as a rule, a very obvious symptom. It will be most marked when caries affects the cervico-dorsal region, and the nerves to the arms are implicated. Paralysis due to this cause will be accompanied by wasting of the muscles and by the reaction of degeneration. Painful contractions as the result of irritation of the motor nerve-roots are extremely rare.

Pressure upon the Spinal Cord (*Compression-paraplegia*).—It has already been pointed out that the most common cause of paraplegia is pressure from the accumulation of inflammatory products between the bone and the dura mater, generally in the upper half of the dorsal region. The result of this pressure upon the cord is to impair its conductivity and to produce a paralysis varying in degree in the parts below the level of the lesion. The rapidity of onset varies greatly, the paralysis taking from a few days to some months to reach a high degree of severity. In rare cases it may occur instantaneously as the result of fracture-dislocation through a carious vertebra, or from hemorrhage, or from the sudden bursting of an abscess into the spinal canal.

An early symptom, and one important from the diagnostic point of view, is an increase in the superficial reflexes. The tendon reflexes also become excessive, and with descending degeneration of the lateral columns, spastic rigidity of the paralyzed limbs takes place. It is less common to find much alteration in sensation. There may, however, be varying degrees of anesthesia, or loss of touch, or pain alone. Loss

of voluntary control of the bladder and rectum frequently occurs. As the pressure on the cord is almost always above the level of the center controlling these acts, the reflex arc remains intact. The bladder, consequently, can empty itself, though involuntarily, and frequently with some periodicity. Retention of urine may, however, occur, and this would be the invariable result of destruction of the lumbar center.

The prognosis of paraplegia following caries may, on the whole, be considered as very hopeful, recovery occurring in the majority of cases. Nothing, however, can be positively predicted of any individual case, however slight, nor does the duration of symptoms for a year or more necessarily preclude recovery. When recovery fails to take place, paralysis both of motion and sensation may remain, though more commonly sensation returns more or less completely, whilst palsy and rigidity of limbs remain.

Diagnosis.—Though, as a rule, in late cases diagnosis does not present any difficulty, at an early stage it is only by a very careful attention to the symptoms of the disease that an error may in many cases be avoided. We would specially mention as significant the marked local rigidity of the spinal muscles supporting the carious spine. This is wanting in those somewhat difficult cases of young and nervous girls who complain of pain and weakness in the back, and who have also a fixed tender spot usually over one of the dorsal or lumbar spines, with in some cases marked hyperesthesia of the skin at this point. The absence, however, of any deformity and of referred pains, and more especially the perfect flexibility of the spine, will serve to distinguish these cases from those of Pott's disease. The diagnosis of caries from new growths will be referred to under the latter heading.

Prognosis.—Owing to the great variations presented by spinal caries and its complications, a mere statistical statement of recoveries and deaths would convey nothing. It may be safely stated, however, that, given no evident complication, general or local, the tendency is always toward recovery when even moderate care is taken. Abscess adds to the risks, for unless strict precautions are taken, the supervention of sepsis aids the tuberculous process. Angular curvature may shorten life by the reaction on the general health of the displacement and cramping of important organs. Thus, in cervical disease the bending forward of the neck, by obstructing the trachea, interferes with the free entry of air; in dorsal disease the approximation of the ribs and limitation of costal movements seriously hamper respiration; whilst dorsilumbar disease, by cramping the abdominal viscera, causes disorders of digestion and gives rise to upward pressure on the diaphragm, impeding deep inspiration and interfering with the heart's action.

Death may be brought about by any of the general complications common to all tuberculous lesions, such as lardaceous disease, cachexia, or acute tuberculosis. Implication of the spinal cord may bring about a fatal termination from acute meningitis and myelitis in rare instances, but more frequently it is the result of compression. In atlo-axoid disease fatal pressure on the medulla may follow dislocation, or a post-pharyngeal abscess, bursting into the pharynx and entering the larynx, may cause death by suffocation.

Treatment.—By Rest.—The indications in the treatment of an

uncomplicated case of spinal caries are to relieve the focus of disease in the vertebræ of the weight of the superincumbent parts, and to provide against jars and vibrations of all kinds. The former of these is of great importance, as the carious process, once established, is largely maintained by the pressure from above. They are met most completely by absolute rest in the recumbent position, and consequently this mode of treatment should be adopted when possible in all cases to begin with. Mechanical apparatus which allows the patient to get about does not, in our opinion, give that rest to the parts so necessary for rapid recovery. In acute cases rest is essential. The recumbent position on a firm bed in a cheerful and well-ventilated room should be adopted. If a child, the patient should be carried out when possible into the open air on his mattress, the same position being rigidly maintained throughout. Except in caries of the upper cervical vertebræ, there is, as a rule, no objection to the employment of an additional wedge-pillow for the principal meals. When restraint is necessary, a strip of some soft material should be carried across the chest, with apertures for the arms to pass through, and fixed to the sides of the bed. Limited movements of the arms, especially in cervical and dorsal disease, must be insisted upon. When the disease is in the cervical region, the patient should be kept absolutely horizontal, and the head steadied by sand-bags. A firm small pillow should be slipped under the neck, to provide support from the occiput to the shoulders. In atlo-axoid disease every care should be exercised to provide against fatal pressure on the medulla by the slipping forward of the atlas on the axis. Even when the onset and course are distinctly chronic, the best results, as regards both duration and deformity, will be obtained by rest for a time.

By Supports.—Some form of mechanical apparatus for supporting the spine will be indicated when all symptoms of acute disease have disappeared during treatment by recumbency, and repair seems to have made considerable headway. In some cases, especially in hospital out-patient practice, where the social position of the patient renders it impossible that he should be nursed in bed, treatment by some form of support from the commencement will have to be adopted. Though invaluable in these cases, it cannot compare with rest in bed, as it fails to remove all downward pressure on the focus of disease and to obviate all jars communicated through the feet, and from the point of view of deformity, treatment by supports throughout is vastly inferior. When abscess is present or paralysis threatening, rest alone must be adopted. For adults, who do not bear prolonged rest on the back so well as children, a jacket may be employed throughout. For the purpose of support the old complicated pieces of apparatus have been practically superseded by the plaster jacket introduced by Sayre, or the poroplastic jacket designed to obviate certain disadvantages attaching to the latter.

As Sayre showed, the acme of support to a carious spine could only be obtained by the application to the body, when extended, of a closely-fitting rigid jacket which prevents all lateral or rotary movement, and which, by embracing the trunk equally at all points, supports the body above the seat of disease while it grasps it firmly below. It thus

relieves the inflamed bone of much of the superincumbent weight. The advantages that plaster has over felt are chiefly these: Its greater rigidity, its cheapness, the fact that the surgeon can himself readily fit it, and that it cannot be taken off by the patient. In applying it the following points should receive attention: Care should be taken in making extension that this should stop short of producing pain or any feeling of strain in the back. All bony prominences, especially the anterior iliac spines, should be protected by pledgets of cotton wool. The lower limit of the jacket should be well down over the iliac crests; above, it should be carried to the armpits, and well up over the chest and back. Ashby and Wright recommend that it should be carried up crosswise over the shoulders, the cervical part being afterward cut out.

When a strong prejudice exists against a jacket that cannot be taken off for toilet purposes, felt softened by heat may be employed. As compared with plaster, it fails in efficiency from the very fact that it can be taken off, from its liability to alter in shape, and from the circumstance that it fits less closely than plaster of Paris. Felt jackets are always weak over the chest and the crests of the ilia, two important fixation-points. In the later stages of caries, however, it gives ample support, and is then in every way the best material to employ. When a sinus exists, the movable jacket is obviously better than one of plaster of Paris.

When a patient is treated at an early stage by the recumbent position, not only may the boss not increase, but it may lessen in size, as we have seen happen on several occasions. This is the more likely to occur when there is but one prominent spine. This result might be expected, since the treatment adopted removes the forces that are displacing the neural arches backward, and direct pressure from behind takes their place. When several bodies are affected and the angle is already well formed, treatment must be directed to supporting the back and lessening the sufferings of the patient that result from his curvature. Any good stays, with firm steels suitably shaped, will serve all purposes, or the felt jacket may be adopted.

In *cervical disease* the felt jackets may be adapted to the case by being continued upward as a collar, closely fitting the neck and moulded above to the chin and occiput to support the head. A better contrivance is an upright steel rod passing up from a suitable jacket to just below the occiput, where, by means of arms projecting from it and controlled by screws, pads are made to support the occiput and chin. Both these methods, while taking off the weight of the head from the spine below, limit lateral and rotatory movements, and are consequently adaptable to atlo-axoid disease. When the disease is below the atlo-axoid joint, Sayre's jury-mast may be successfully employed.

A slight iron framework, fixed below to the body by means of a plaster jacket, supports a steel rod, which curves forward from behind over the head. To the extremity of this, which is 4 inches above the head, is attached a swivel cross-bar, which carries a leathern sling by means of which the chin and occiput are supported. Sayre claimed for this jury-mast that the head was free to move around while still supported, and that thereby the patient's comfort was much increased. The objection to this apparatus is that the steel bar prevents the child lying down properly, and in a short time gets bent or displaced; and, moreover, in the recumbent position it ceases to exert any traction on the head. While we have used it successfully in adults and older children, we do not recommend it for very young children, and it is not suitable for atlo-axoid disease, on account of the rotation allowed.

Operative Treatment.—*Abscess.*—The treatment for abscess in connection with spinal disease should be conducted on lines applicable to chronic abscess in connection with bone elsewhere. As soon as abscesses become evident, they should be opened and their contents thoroughly evacuated, the question of drainage being determined by the special exigencies of each case. In general, however, it may be said that if the abscess can be reached at all points, and all inflammatory products

removed, the case is a suitable one for immediate closure as first carried out by Barker. Essential points to be attended to are thorough cleansing of the sac-wall and strict antisepsis from first to last.

An incision having been made into the abscess and the contents allowed to escape, the interior is carefully explored and any septa present are broken down. Water of a temperature of 103°–105° F. is poured, or, better, conveyed by Barker's flushing scoop, into all parts of the cavity. At the same time the walls are gently scraped to remove all adherent material. When scraping is likely to be attended by such risks as opening the peritoneum, the wall may be rubbed with sterilized sponges. The cavity having been well flushed and mopped dry, an emulsion of iodoform and glycerin is poured in. The greater part should be allowed to escape before the wound is finally closed, or, better, the abscess-cavity should be wiped out with sterilized sponges, leaving only such an amount of iodoform as will adhere to the walls.

A *postpharyngeal abscess* should be opened promptly, to prevent the possibility of a spontaneous opening into the pharynx, with the immediate risk of suffocation, and later of septic infection. It should be reached, as was suggested by Hilton, by an incision carried along the posterior border of the sternomastoid, or where most superficial. Opening the abscess through the mouth should be done only in an emergency, the patient lying on his side with the head inclining a little over the side of the couch, to diminish the likelihood of pus entering the larynx.

Dorsal and *lumbar abscesses* should be opened at the most prominent point by vertical incisions, the further treatment being conducted on the general lines laid down above.

Psoas abscess may be dealt with in two ways—either by an opening in front in the groin, or behind in the lumbar region. The former alone is objectionable, if drainage will be required, since the wound is very likely to become septic, especially in children, from the proximity of the excreta. Moreover, it does not admit of the upper part of the cavity being reached for purposes of exploration and cleansing. In spite of the difficulties that may attend the operation for reaching the upper end of a psoas abscess in many cases, the lumbar opening is the one that should be adopted. When the abscess has travelled as far as the groin, an opening should be made in the latter situation to facilitate the flushing and cleansing of the cavity, the anterior wound being sewn up afterward. The operation of cutting down upon the psoas sheath from the loin is not altogether free from risk of wounding the peritoneum, and the difficulties may be increased by free bleeding from the lumbar arteries.

Exploration of Bodies of the Vertebræ.—In those cases in which an abscess is present the bodies may be explored with comparative ease, as was first suggested by Treves in 1884, and in some cases sequestra and portions of diseased vertebræ removed. When, however, an abscess does not exist, the success of any attempt to deal with carious foci in the spine will be in most cases very problematical. The technical difficulties of exposing the anterior surfaces of the vertebræ are considerable, and this applies especially to the dorsal region, though even here the bodies have been successfully attacked by resection of the posterior extremities of the ribs. The dorsilumbar and the lumbar

region is more accessible, but unless an abscess is present, there is difficulty in getting working room without endangering the peritoneum.

In caries of the sacrococcygeal joints and of the coccyx, removal of this bone is a sure and easy method of cure.

Treatment of Paraplegia.—Since the tendency in these cases, especially in children, is toward recovery, they should be treated in the first instance by rest in the recumbent position. This may be combined with double extension; and Watson Cheyne, who speaks highly of this mode of treatment, states that recovery by this means commences earlier and proceeds more rapidly than in recorded instances of laminectomy. Improvement was noted by him within three days. A weight of three pounds is applied to the head and a similar weight to the legs, not for the purpose of opening out the curved spine, but to tire out the muscles in the diseased area, which by their contraction keep up the inflammation.

Under certain circumstances, however, laminectomy holds out the only hope of recovery. Operation is indicated (1) when, in spite of rest and appropriate mechanical treatment, symptoms either persist or steadily increase; (2) when caries of the arches exists, and removal of the diseased focus seems practicable; (3) when symptoms directly threatening life are present (Thorburn). The question of when to operate is not one that can be definitely settled. Each case must be decided on its merits, and the time of operation decided by the particular symptoms present and the results of treatment. A sudden onset of symptoms, as indicating the bursting of an abscess into the canal or the displacement of a sequestrum, would suggest immediate operation. A fracture-dislocation occurring through a carious vertebra would not be benefited, and should contraindicate all interference, as would also the presence of extensive tuberculous disease elsewhere.

Immediate Reduction of the Deformity.—This can be effected by means of extension and counterextension, aided by direct pressure over the projecting spines, the patient being under chloroform. The deformity is corrected, and the patient's trunk surrounded by a plaster-of-Paris jacket. Since this mode of treatment was first carried out by Chipault in 1893, a number of cases have been submitted to rapid reduction of the curvature; but the results do not warrant our recommending this mode of treatment, and on *a priori* grounds it seems that any benefit likely to accrue is more than counterbalanced by the grave risks that such a process involves.

SPONDYLITIS DEFORMANS.

This is an affection characterized by alteration in the normal curves and restriction of the ordinary movements of the spinal column.

Pathology.—The changes in the spine that give rise to this disease are identical with those that affect joints generally in rheumatoid arthritis. The articular cartilages and the intervertebral disks become absorbed, the bones become altered in shape, and bony outgrowths take place from the margins of the joint-surfaces and from the contiguous borders of the vertebral bodies (Fig. 415). More or less restriction of movement results, and this may go on to absolute fixation of a considerable portion of the spinal column.

Ankylosis is brought about in three ways: By the locking and occasionally by the coalescence of the osteophytes springing from adjacent vertebræ; by a direct bony union of the vertebral bodies; and by a conversion of the ligaments into bone. This osseous change most commonly affects the anterior common ligament. Very rarely the spines and laminæ are found united by bone. The costovertebral articulations may be similarly attacked.

The lower dorsal and lumbar vertebræ are most commonly affected; less frequently those of the upper cervical region. The atlanto-occipital and atlo-axoid articulations may present the characteristic changes, and the odontoid process may be considerably enlarged.

It is a disease of later middle or advanced life, but cases may be met with in young adults and even in children. It is more common in males than in females.

Symptoms.—The onset is gradual, commencing with pain, which may be persistent, and stiffness. The pain may be felt in the small of the back, preventing stooping, or in the neck, interfering with movements of nodding and rotation. The patient sometimes notices that the stiffness affects his chest, restricting the ordinary movements of respiration. An alteration in the figure slowly takes place. There is a gradual diminution in stature, and with this an inability to stand upright. In a case that has been progressing for some years the back presents one long curve with the convexity directed backward; the head is craned forward, and the chest sunk. Movements are greatly restricted, and there may even be complete fixation of a considerable portion of the spinal column. When the costovertebral joints are affected, breathing is carried on almost entirely by the diaphragm.

FIG. 415.—Spondylitis deformans. Specimen showing lipping and ossification of ligaments on the right side of the spine (Guy's Hospital Museum).

FIG. 416.—Erosion of vertebræ by aneurysm. The intervertebral disks are intact (Guy's Hospital Museum).

The changes in the spine may coincide with similar changes in joints elsewhere, or may be confined for a long while to the spinal column and the costovertebral articulations. The bony outgrowths from the vertebræ may compress the nerves in the intervertebral foramina, giving rise to neuralgic pains in their distribution. Compression of the cord itself scarcely ever occurs.

Treatment will be conducted on lines similar to that employed for rheumatoid arthritis occurring elsewhere.

EROSION OF VERTEBRAE BY ANEURYSM.

The bodies of the vertebræ, most frequently those of the dorsal region, may be absorbed by the pressure of an aortic aneurysm (Fig. 416), and in some cases an angular curvature is produced. Two or three vertebræ are usually affected, the bodies being destroyed while the intervening disks remain comparatively unaffected. Erosion is usually attended by a continuous boring pain in the spine, while the pressure on the adjacent nerves gives rise to severe neuralgic pain in their distribution. The aneurysm may reach the cord and compress it, with the production of the usual symptoms, and it may even rupture into the canal.

Diagnosis from growth will be effected by the presence of other signs pointing to aneurysm.

TUMORS.

Tumors of the Spinal Column.—The spine may be the seat of either primary or secondary growths, or may be invaded by tumors originating in neighboring structures.

Of primary growths, *sarcomata* are the most common, originating either within the bone or from the periosteum. Other forms of primary growth are very rare. A *hydatid cyst* may develop in a vertebral body, or a *chondroma* or *exostosis* grow into the spinal canal, compressing the cord. *Carcinoma* is the most common secondary growth met with.

Symptoms.—The slow-growing tumors will give rise to symptoms of compression that are marked by their extreme chronicity. On the other hand, the malignant growths are characterized by the acuteness of their course and the severity of the pain.

Pain is a most prominent symptom throughout. While seated sometimes in the spine itself, in association with local tenderness and rigidity, in its most severe form it is felt in the distribution of the nerves the roots of which are involved in the growth. It is intensified and often rendered agonizing by the slightest movement. Painful muscular contractions and localized paralysis may result from compression of motor nerve-roots. As the result of the infiltration of the bodies of the vertebræ with soft growth, these may fall together, with the production of angular curvature (Fig. 417). This may take place with such rapidity that deformity is noticed within a few weeks of the onset of symptoms. Curvature is not, however, invariable. Extension of the growth to the spinal canal will lead to compression of the cord, with the production of symptoms similar to those described in Caries.

A rapid onset of paralysis is said by Gowers to occur more frequently in growth than in caries, all movement being lost in from twelve to twenty-four hours.

Diagnosis.—From caries, to which it presents many points of resemblance, malignant growth may be distinguished by the following characters: Pain is much more severe from the first, and is intensified by the slightest movement; the course of the disease is very rapid, and is measured by months; in spite of rest and appropriate treatment, there is a progressive increase in the symptoms. Age is an important factor. In the first half of life caries is by far the most common cause of curvature; in the second half caries and growth occur with about equal frequency. The presence of an abscess in connection with the spine, or tuberculous lesions elsewhere, will point to caries. The possible presence of an aneurysm or a growth originating outside the spinal column as the cause of severe neuralgic pains from pressure on nerves should be borne in mind.

FIG. 417.—Secondary cancerous deposits in the bodies of the dorsal and lumbar vertebræ. The eleventh dorsal vertebra is reduced almost to the dimensions of an intervertebral disk, with the production of an angular curvature (Guy's Hospital Museum).

Treatment is limited to the relief of pain.

Tumors in the Spinal Canal.—These may originate in the cord, from the membranes, or outside the dura mater. Tumors outside the membranes in most cases spring from the vertebral column, and are of a malignant type. Very rarely lipomata and parasitic tumors, chiefly echinococci, develop in the tissue between the bone and the dura mater.

Tumors of the cord are far more rare than those of the membranes. They comprise most frequently gliomata, sarcomata, and gummata; less often, tuberculous masses are found. Growths arising in the membranes are in a large proportion of cases sarcomata and myxomata, less frequently tuberculous nodules and gummata, and rarely benign growths such as fibromata, lipomata, and angiomata.

Tumors are found most frequently in the dorsal region. They are usually single, but sometimes two or three coexist, neuromata of the nerve-roots being frequently multiple.

Symptoms.—The earliest symptom, and one prominent throughout the course of the disease, is pain, felt in the distribution of the nerves whose roots are compressed by the growth. Unilateral to commence

with, it becomes bilateral as the tumor increases in size. It is generally severe and neuralgic in character. Pain is not, as a rule, felt in the spine until the growth is large enough either to press on the dura mater and bone or to erode the vertebræ. Tenderness on pressure over the spines may be elicited, but is not, on the whole, very common. Muscular spasm due to irritation of motor nerve-roots occurs not infrequently. All these symptoms are most marked in meningeal tumors.

As the tumor increases in size it will compress the spinal cord, giving rise to symptoms similar to those mentioned under the head of Paraplegia due to Caries. The paralysis is of gradual onset in most cases. Occasionally, crossed motor and sensory paralysis results from one-sided tumors—paralysis and hyperesthesia on the side of the lesion, anesthesia on the opposite side.

Treatment.—If there is reason to suppose that the tumor is syphilitic, the usual remedies should be energetically employed. A month will probably suffice to indicate the nature of the disease and the advisability or not of further treatment on these lines. Tuberculous tumors will be suspected from the co-existence of tuberculous lesions elsewhere. They may yield to general treatment.

Other tumors steadily progress, and, apart from operation, treatment can be directed only to an amelioration of symptoms. The prognosis being necessarily hopeless, the question of operative interference becomes an important one, and will be the more readily adopted now that the possibility of successful removal is established beyond doubt. The operation will be conducted on similar lines to that for the relief of other forms of compression (see Laminectomy). Tumors of the spinal cord are not amenable to treatment. As, however, growths in this situation cannot always be diagnosed from those originating in the membranes, operative procedures will in the first instance partake of an exploratory character. Tumors of the membranes are most often met with, being five or six times as common as those in the cord itself. As Allen Starr points out, an unfavorable feature in the prognosis is the frequency of sarcomata, which form over a third of all tumors found. In most cases that have recovered the growth was of a benign character—lipoma, fibroma, angioma. The results of operation bring out very clearly the importance of early recognition of the disease and removal of the growth before irrecoverable changes have taken place in the cord.

SCOLIOSIS (LATERAL CURVATURE OF THE SPINE).

By scoliosis is implied a deformity characterized by lateral deviation of the spinal column, associated with rotation of the bodies round a vertical axis.

Pathology.—It should be borne in mind that the erect attitude of the spinal column is maintained only by muscular activity. When from fatigue the erect posture is departed from, certain positions are assumed, both in sitting and standing, which involve less expenditure of energy. In the healthy, vigorous individual, owing to a due balance being preserved between rest and activity, there is no tendency for

these "attitudes of rest" to pass beyond the limit of what may be considered a perfectly normal physiological condition. But in the weakly and in those easily liable to fatigue, such positions, being habitually indulged in, will in course of time lead to the permanent impression on the structures of the spinal column of the curves characterizing these attitudes, and later to their exaggeration. An ordinary example of an attitude of rest, such as that known as standing at ease, will serve to make the above clear. In this position the patient rests, say, on the right leg, with the hip and knee fully extended, the weight of the body being transmitted through this leg. The left leg is flexed at the hip and knee, and the pelvis is consequently tilted down to the left-hand side. The lumbar spine is thus thrown over to the left. In order to restore the balance of the body, the spine must be curved over to the right, and thus there results a curve in the lumbar region with the convexity to the left. There follows, of necessity, a compensatory curve in the dorsal region, with the convexity to the right, for the purpose of balancing the upper part of the trunk on the lumbar curve. In this form of curvature the primary curve is in the lumbar region, the dorsal one being secondary and compensatory. The same results from sitting and lounging habitually in certain attitudes. Lateral curvature is brought about most commonly in this way. It exhibits itself mostly in children and young adults, most often in girls. They are usually observed to have an ill-developed muscular system, and belong to the class of people who are soon tired. There is often an hereditary history of curvature, direct or collateral, on the mother's side; and where one girl in a large family suffers from scoliosis, flat-foot or knock-knee is often found in another member of it.

Healthy adults may, as the result of the constant performance of certain forms of labor, acquire a permanent curvature of the spine, which, as in the case of the weakly, is to be regarded as the fixation of what is a normal physiological attitude. In this case, however, it is an attitude of activity that permanently impresses itself on the spinal column. This form usually results from carrying heavy weights on one shoulder or in one hand, and the curve produced is usually a long single one involving the whole of the dorsal and lumbar spine, with the convexity to the side on which the load is carried.

Lateral curvature is seen occasionally in rickety children, the mechanism of production being the same as in adolescents. A disparity in the length of the legs, as from old fracture, hip-disease, congenital hip dislocation, or infantile paralysis, will also be productive of scoliosis, and contraction of one side of the chest from empyema or pleurisy may lead to the same result.

On account of the unequal compression of the vertebral disks brought about in any of the preceding ways, the cartilages become flattened on the side of the concavity. If the factors maintaining the curve persist, the bodies in time become wedge-shaped.

Rotation of the bodies of the vertebræ on a vertical axis always accompanies, and is a necessary consequence of, the lateral deviation (Fig. 418). The bodies face round toward the convexity, while the spines are directed toward the concavity, so that the deviation of the spinous processes does not represent the full lateral curvature. As the result of the rotary movement, the transverse processes on the side

of the convexity are directed posteriorly, carrying with them, in the dorsal region, the ribs, the angles of which become very prominent. In the upper dorsal region the scapula will be pushed farther than normal from the mid-line. The shoulder on the side of the convexity will be elevated, and this is frequently the first sign noticed by the patient. The "outgrowing shoulder" (*i. e.*, the scapula) and "the shoulder carried higher than the other" are modes of expression often employed by parents in describing the affection. On the side of the

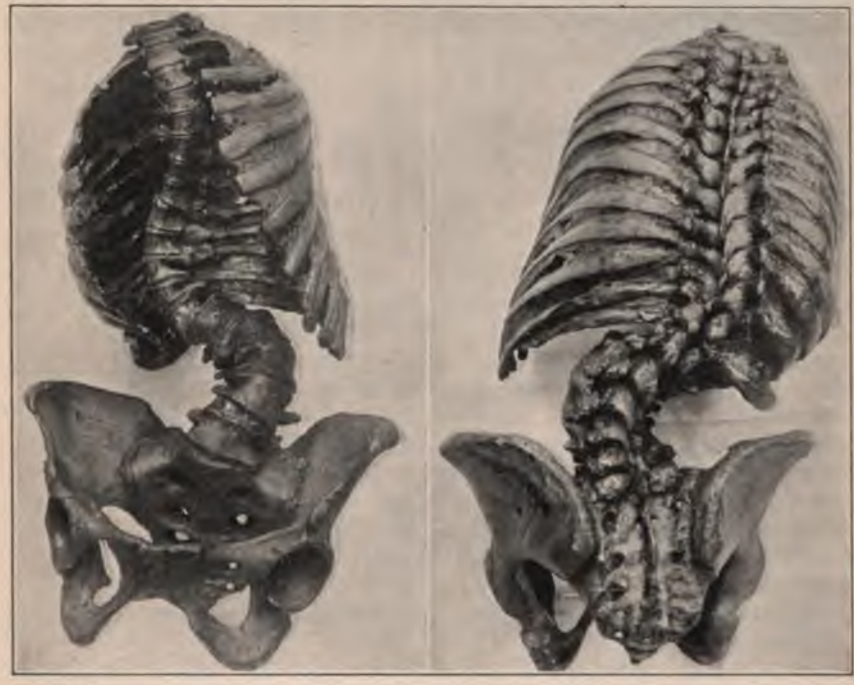

FIG. 418.—Skeleton from a case of lateral curvature, showing lateral deviation and rotation of bodies (Guy's Hospital Museum).

concavity the capacity of the chest is much diminished, the ribs being crowded together, whilst the breast is sometimes noted as more prominent than on the opposite side.

Symptoms.—The patient should be stripped to the hips, and the clothes held by a nurse, to allow the patient's arms to hang free and also to prevent any constriction or concealment of the loins. The vertebral spines are first examined for any deviation from the middle line. The loins are then carefully compared as regards symmetry, and it is here that the earliest signs of curvature are noted in the majority of cases. In the slightest cases there will be a want of symmetry in the loins—on the side of the curvature, a curved outline or at least a straight one; on the concave side, a more or less marked dipping in or creasing of the soft parts. We regard this as the most important objective sign of early scoliosis.

In a well-developed case a posterior projection in the loin of the

erector spine on the side of the convexity, and of the angles of the ribs in the dorsal region on the opposite side, will be observed. The prominence of the scapula and the heightening of the shoulder will also be obvious. Examined in front, the breast on the side of the dorsal concavity will project more than that on the other side. In advanced cases all the above signs will be immensely exaggerated, especially in the dorsal region, where the rotation may be so marked that the angles of the ribs form a ridge running more or less parallel with the spine, and easily mistaken for it by a careless observer.

The general health of the patient and the musculature should be carefully noted, for no cure can be effected so long as they remain defective. Pain in early cases is generally confined to a general back-ache, muscle-weariness, and an aching under the blade-bones. In advanced curvature the ribs may be so pressed together as to cause intercostal neuralgia. Shortness of breath, palpitation, and dyspepsia may be complained of in severe cases, from limited movement of the ribs and diminished capacity of the chest and abdomen.

Treatment.—Formerly, mechanical support was regarded as the essential in treating lateral curvature; and while there is no denying the comfort given by suitably chosen appliances, they are likely, when discontinued, to leave the patient in a more helpless state than before. Having largely taken the place of the patient's muscles and reduced to a minimum the exertion necessary to maintain the erect position, the patient becomes less and less fitted to be again independent of artificial support. However, in patients with advanced curvature strong supports will be found of very great value to enable them to remain useful units of society; though even these cases may obtain relief from some of their complications, such as neuralgia, oppressed breathing, etc., by using some of the exercises indicated in less severe forms of scoliosis.

The treatment of lateral curvature falls under three heads: 1. Rest; 2. Exercises; 3. Supports.

Rest.—Few cases come before the surgeon in which absolute rest is not at first required. Most scoliosis cases, when they first present themselves, are overwrought and unable to keep upright, sinking every moment into the halting position. Confinement to a reclining board or a flat couch is necessary, and no exercise, not even sitting up to meals, should be allowed. The general health and environment should be attended to and tonics administered. After the first few days, massage of the muscles of the back should be carried out daily, and this on alternate days can be extended to the whole body. This regimen should be continued until the health is obviously improving, the muscles developing, and all rachialgia gone. Exercises may then be substituted for the massage, and the patient may sit up a short time for the midday meal. This stage is usually reached in about four weeks. When the exercises have been learnt, and the patient is accustomed to them, and not wearied by them, she may begin to take short walks of fifteen minutes' duration, being previously fitted with suitable corsets. All rest must still be taken lying down. In fact, sitting is the last position allowed. The length of time during which the hori-

zontal position should be maintained for purposes of rest varies in every case, but may extend to twelve or even eighteen months.

Exercises.—There are numerous forms of exercises recommended; but, provided they fulfil certain conditions, detail may be disregarded. The conditions are active exercise of the muscles of the back and shoulders, regularly carried out in such a way that there may be at the same time an extending force at work on the spine itself. The following is an example of an exercise without apparatus. Extend the arms fully over the head, and let the hands meet and clasp; now, straining the arms and trunk upward as far as possible, bend slowly forward at the loins, as though in the act of making a plunge; then by reverse action recover the original position. In mild cases the spine may be seen to straighten at once. On examining a case it is well to make the patient go through this exercise, as the surgeon can thereby form an opinion of the extent to which the curvature can be obliterated. Subsidiary exercises, which fail, however, in producing extension, are the ordinary arm-exercises, with or without light clubs, which are mostly done at gymnastic classes.

Of exercises with apparatus, the cross-bar hanging from two parallel ropes is a favorite. It has two objections: the hands are kept at the same level, and it is too often used merely to swing from, which involves no active muscular exercise. We prefer to this a simple rope hanging from the ceiling. Up this the patient climbs hand over hand till off the ground. At this stage the hand on the side of the dorsal concavity should be the higher on the rope, and thus a greater force brought to bear by means of the trapezius of that side than when the hands are on a level. After remaining in this position a few seconds, the patient climbs down, repeating the process again, until when used to it she can carry it out for ten minutes twice a day.

For the details of other exercises, such as Sayre's swing exercise and Schmid's exercise, we must refer to special works on the subject. In both of these exercises direct force is exerted upon the spinal column by means of a head-piece.

Supports.—All rigid supports, such as Sayre's and poroplastic felt-jackets, as well as the elaborate ones of leather and steel manufactured by every instrument-maker, should be reserved solely for incurable cases—that is, cases that are too far advanced to admit of being again made "straight," and in whom, even if the tendency is not to get worse, there are the various symptoms dependent upon compressed viscera. For all cases under treatment with a view to improvement, no further support is required than that given by specially made corsets. There are, however, special points in their construction which alone can make them perfect. They should reach low down over the hips, so that a pelvic strap which forms part of the corset may get a firm grip round the pelvis, and thus supply a *point d'appui* for the steels passing upward; and secondly, the springs should be made of thin metal and suitably sprung, so that without taking from the patient the necessity of using her own muscles, they give just enough elastic support to ease that extra muscle-strain which these patients are so ill able to bear.

CHAPTER XXVI.

SURGERY OF THE PERIPHERAL NERVES.

FOR information upon the etiology, symptoms, and treatment of those lesions of the peripheral nerves which are not strictly surgical, the reader is referred to standard works upon Neurology. In the present chapter only those considerations which are of direct surgical importance are discussed.

WOUNDS AND INJURIES OF NERVES.

Contusions.—Traumatic lesions of nerves range in severity from slight contusions to complete destruction.

Disturbances of function may result from contusions, stretchings, or pressures. They vary from the numbness, tingling, and motor paralysis of a few moments' duration to entire loss of motor and sensory functions, which may require months or even years for complete restoration. In some instances, indeed, the impairment is permanent.

Contusions usually affect those nerves which lie in close contact with bones, or which are separated from the skin merely by thin tissues or fibrous aponeuroses—the ulnar at the internal condyle, the anterior tibial at the head of the fibula, the musculospiral behind the humerus. Nerves more deeply placed may share in the general bruising which affects thick soft parts, as in crushing of the thigh and of the upper arm, but nerves thus placed are injured only with difficulty. At the Massachusetts General Hospital one case has been observed in which the nerve retained its function after the upper arm had been run over by a freight car. Nothing was preserved except the nerves, blood-vessels, and skin. Years afterward the forearm was found unimpaired in nerve-force, though the middle of the upper arm was without bone or muscle.

The brachial plexus is not infrequently the seat of direct violence from dislocations of the head of the humerus and from other injuries that stretch the plexus and bruise it against the clavicle.

Contusions may cause a local irritation of the nerve, which at times results in a local neuritis. The nerve becomes swollen and congested.

The **symptoms** of contusion come on immediately, and are the effects of the initial violence. At first there may be only a tingling sensation along the course of the nerve, with more or less pain. A sensation of heat is often felt at the peripheral distribution of the nerve. These symptoms may be followed by complete sensory and motor paralysis. When the results of pressure upon the brachial plexus appear gradually, they are probably owing to the secondary and prolonged pressure of the dislocated bone rather than to the immediate bruising.

Paralysis of the circumflex nerve from falls upon the shoulder is often observed—frequently associated with impairment of the motions of the shoulder, especially of rotation. In these cases it is hard to see

how a nerve can be contused when so deeply placed as the circumflex, fully protected as it is by the deltoid.

Treatment.—Contusions usually result in recovery even after complete paralysis. Convalescence is hastened by the use of electrical stimulation and massage. Should the paralysis persist after reasonable efforts at palliative treatment and reasonable time for spontaneous recovery, the nerve should be exposed and its exact condition determined.

FIG. 419. — Musculospiral nerve as it appeared in a case of paralysis from contusion and pressure between the humerus and the tendon of the triceps (from specimen supplied by E. W. Taylor).

Pressure.—Pressure long continued will produce a paralysis more or less complete. The pressure may be of one or two hours' or of months' duration. Examples of the former are seen in the effects of the application of tourniquets, cords, bandages, and of sleeping on the arm; of the latter, in the encroachment of neoplasms, calluses, and displaced fragments of bone.

The musculospiral is especially liable to pressure between the lower end of the humerus and the flat tendon of the triceps. Occasionally the nerve is caught and compressed between the ends of a broken bone. Paralysis of the musculospiral nerve, from its position close to the humerus, illustrates also the danger attending the use of the elastic tourniquet in bloodless distal operations. Such a mishap, though its effects are but temporary, is peculiarly disquieting, and makes inadvisable the prolonged use of a tightly applied elastic tourniquet.

A rare form of paralysis, probably caused by pressure, though possibly by stretching, is that of the brachial plexus during operations upon patients in the Trendelenburg position. This condition occurs occasionally after prolonged elevation of the arms, the plexus being pressed against the head of the humerus or under the surface of the clavicle, or held up against processes of the deep cervical fascia. The arms should never be held thus in the Trendelenburg position, but rather folded over the chest.

Another paralysis is sometimes seen after the arm has hung over the edge of the table during a prolonged operation. This is generally a musculospiral paralysis, and is caused by the pressure of the arm against the sharp edge of a table.

Another form of pressure-paralysis is occasionally caused by the use of crutches. A loss of power is noticed in the muscles supplied by the musculospiral, with more or less tingling and anesthesia in its area of distribution. Those paralyses caused by a transitory pressure disappear more or less promptly upon the removal of their cause.

Paralyses occur also from the pressure of inflammatory exudations, from the strangling of surrounding neoplasms, as well as from direct compression between neoplasms and adjacent structures; as, for example, facial paralysis in the course of inflammations of the mastoid; and in carcinoma and other infiltrating neoplasms of the parotid;

paralysis of the posterior crico-arytenoids from pressure of thyroid or mediastinal tumors upon the recurrent laryngeal nerves; affections of the intercostal nerves from the pressure of aneurysms.

A marked surgical interest attaches to those symptoms of nerve-involvement which appear slowly as the result of compression from cicatrices, accidental or surgical (Fig. 420). Whether the manifestation

FIG. 420.—Right external popliteal nerve, showing involvement in a cicatrix. Myelin has disappeared, and the normal nerve-structure has been replaced by a dense connective tissue (Weigert, low power). (From specimen supplied by E. W. Taylor.)

be pain or loss of power, the existence of cicatricial tissue in the course of the affected nerve suggests a probable cause. Such affections, slowly appearing after injury or operation, unrelieved by palliative treatment, require surgical exploration to determine the exact condition and to afford relief.

Treatment.—Pressure-paralyses are usually self-evident. Those appearing after prolonged application of tourniquets or after unusual positions are so clearly the result of a pressure already relieved that proper measures of treatment do not require a consideration of the exact lesion. Those caused directly or indirectly by a violence sufficient to produce laceration; those that may depend upon an unrelieved pressure, as upon bony growths, calluses, dislocations, entanglements in contracting scars—all such cases raise the question of operative interference, and therefore of a more or less exact diagnosis. For no time should be lost in palliative treatment if there is a solution of continuity, and none if there is an unrelieved pressure. It is impossible in all cases, however, to say that the causative lesion no longer exists, that the pressure is relieved, or even that the nerve is undivided. To wait until the failure of palliative treatment has demonstrated the need of surgery requires from six months to two years. It is necessary, therefore, in traumatic cases to explore early, not only for the foregoing reasons, but for the reason that the earlier the pressure is removed or the sooner the suture is applied, the better the prognosis.

Paralyses from the pressure of dislocated bones require a reduction of the dislocation. If reduction is impossible, it may be necessary to resect the bone, especially the dislocated head of the humerus. Paralyses accompanying fractures may require freeing of the nerve from an imprisoning callus or from compressing fragment-ends.

Traumatic pressure-paralyses, however, usually require no operative interference. It is only when palliative measures—electricity, massage, showering, strychnin—fail after faithful use for four to six or eight months (according to the degree of paralysis) that the nerve should be exposed at the seat of injury. Relief of pressure is all that is essential, though one must be prepared to find, instead of a contusion, complete destruction of the nerve.

Stretchings.—That the stretching of a nerve is sufficient to interfere with its functions, particularly motor, has been demonstrated by the effects produced upon muscular spasm by the stretching of the supplying nerve; for example, stretching the facial nerve for spasm has caused a transitory facial paralysis.

The frequency as well as the importance of accidental stretching of a nerve is inconsiderable, unless the paralysis noted in a foregoing paragraph as occurring after prolonged Trendelenburg posture is owing to a stretching of the brachial plexus rather than to pressure. Stretching, to be paralyzing, must be considerable; for example, stretching of the sciatic for neuralgia rarely causes functional disturbances. Moreover, stretching of the spinal accessory generally fails to relieve permanently the sternomastoid spasm. Although by stretching it seems difficult to cause symptoms of functional disturbance, yet cases do occur in which functional impairment can be explained in no other way. Such, for instance, is that following falls in which the weight of the body is suddenly thrown upon the over-extended palm. Paralysis of the brachial plexus after prolonged operations upon patients in the Trendelenburg position may possibly be caused by stretching rather than by pressure upon the clavicle. In paralysis from stretching, surgical intervention is rarely if ever required.

Dislocation of Nerves.—Nerves are sometimes thrown out of their normal positions in relation to bony prominences. The ulnar, from its groove behind the internal condyle, is most frequently dislocated, and the dislocation is sometimes habitual. The peroneal nerve is sometimes displaced in fractures of the tibia (Deaver). From observations on the cadaver it has been shown that when the ulnar is freed from its bed, flexion of the elbow dislocates it. Sometimes violent flexion will tear the nerve from its bed.[1] According to Wharton[2] the symptoms depend upon the method and the severity of the injury—varying from a tingling sensation to complete paralysis.

The **causes** of dislocation are muscular violence and direct violence, and, in the case of the ulnar nerve, fracture of the internal condyle.

Treatment.—Most cases require operative interference to hold the nerve in place; though sometimes replacement, rest, anodynes, and applications are sufficient (Deaver).

The ulnar nerve is exposed and replaced in its normal position, being

[1] Dennis's *System of Surgery.*
[2] *Amer. Jour. Med. Sci.*, Oct., 1895; report of 13 cases.

held there by flaps from the triceps or by suturing the inner border of the tendon of the triceps to the muscular aponeurosis of the flexor group. Replacement of the nerve is followed by disappearance of symptoms. In no case has neuritis followed. In habitual dislocations Kölliker advises deepening the groove and suturing the parts, the cicatrix tending to keep the nerve in place.

Lacerations, Sections, Crushings.—Injuries to nerves, with more or less complete division of their fibers, direct crushing violence with actual loss of substance, incised wounds with partial or complete division, are, from every point of view, of the greatest importance.

The commonest result of violence applied directly to the nerve is section, partial or complete. This is usually caused by knives, edged tools, glass, and bullets. The nerves at the wrist are those most commonly injured in this manner, in which case the tendons are, as a rule, also divided; less frequently injured are the nerves at the elbow, and in the upper arm, the leg, and the thigh. Rarely other nerves are wounded—the facial, especially during operations upon or about the parotid, the sciatic from falls upon glass, the pneumogastric or phrenic from incised or gunshot wounds. The nerve-trunk may be partially or completely divided. Lacerated wounds of nerves result from blows of great violence by which the soft parts are crushed and the bones comminuted. In such cases the destruction may involve a narrow section or several inches of the nerve. The whole trunk may be completely destroyed throughout the area crushed; it may be partially destroyed, a few fibers remaining intact through an irregular shreddy mass of variable extent.

Diagnosis.—The condition of the nerve may be determined by direct examination of the open wound. In some instances, however, the skin is unbroken. Whenever an exact determination of the injury by direct inspection is impossible, the nerve implicated can usually be demonstrated by the existing paralysis, whether motor or sensory or both. The muscular groups paralyzed and the skin-areas affected will enable the surgeon, from anatomical knowledge, to arrive at a correct deduction. The diagnosis as to the seat of the lesion in a given nerve will depend upon the point to which the paralysis of muscular groups rises. A paralysis affecting the forearm, but not the upper arm—for example, the extensors of the wrist, but not the triceps or the supinator longus—will indicate in a general way that the injury is below the musculospiral groove.

It may be impossible without exploration to discriminate between contusions and lacerations. Between a partial and a complete division of fiber the diagnosis is difficult. The cause of the injury, the manner of its reception, the extent of complicating lesions, the completeness and suddenness of functional impairment must all be taken into consideration. In case of doubt operative exploration is indicated.

Treatment.—In case the nerve is found to be bruised, even though severely, but not divided or destroyed, it should not be disturbed. Whenever a nerve is found divided, it should immediately be sutured (see Nerve-suture). Partial division requires suture of the divided portions, the undivided fibers guiding and hastening the regenerative process. When there is extensive loss of substance, the distance-suture methods

are required. Accidental sections of nerves during operations should be immediately repaired. If the accident is not discovered until after recovery from the anesthetic, a secondary suture is imperative as soon as practicable.

Motor fibers are sometimes injured by the avulsion of sensory nerves. When the infra-orbital nerve is torn out, for example, the motor filaments of the seventh to the upper portion of the mouth are often temporarily paralyzed. Avulsion of the third division of the fifth at the foramen ovale, or removal of the Gasserian ganglion, usually involves the motor filaments supplying the muscles of mastication.

OPERATIONS ON NERVES.

Nerve-suture.—All lesions of nerves producing solution of continuity require, sooner or later, suture of the divided ends. When these ends can be closely approximated, suture is easy and satisfactory; when there has been a loss of an inch or more, devices are necessary by which the intervening space may be bridged over. Simple suture demands that the nerve-ends be brought into accurate apposition and

FIG. 421.—Varieties of nerve-suture.

FIG. 422.—*a–e*, Varieties of nerve-suture; *f, g*, nerve-grafting (after Willard).

fastened there. In recent wounds the divided ends will fall into easy contact; in healed wounds it may be necessary to stretch both distal and proximal trunks before applying suture.

The ends should first be carefully trimmed with the knife, if necessary, so that they present to each other a clean-cut surface. The ends to be sutured may be fitted to each other in various ways, according to the shape and extent of the lesion, the ease of approximation, and other considerations (see Figs. 421, 422). Before suture is applied the divided

nerve-trunks should be allowed to fall into a position as natural as possible, anterior surfaces being brought to anterior, posterior to posterior. If the ends lying naturally in the wound do not touch each other, they should be stretched enough to permit approximation without undue tension.

The sutures may be placed directly through the nerve-trunk, or through the sheath only. If through the whole nerve, only three or four sutures are required. It has been demonstrated that no injury is done by transfixing the nerve (see Figs. 421–423). The preferable way is to bring the sheaths together with numerous fine sutures, because in this manner a very perfect and strong joint can be made. In nerves as large as the musculospiral, ten or fifteen sutures may be used; in smaller branches, two or three; in the smaller nerves—the facial or the posterior interosseous, for example—a single suture will suffice.

FIG. 423.—Nerve-suture.

Many surgeons prefer fine catgut for suturing, using silk or chromicized gut only when the tension is great. Fine silk is preferred by

FIG. 424.—Nerve (rabbit) forty-six days after section, showing almost complete disappearance of the nerve-fibers. Deeply staining portions are remains of myelin, not yet completely disintegrated. The nerve is cut in cross-section (Weigert, oc. 4, im. $\frac{1}{12}$). (From specimen supplied by E. W. Taylor.)

the writer, because a better approximation is possible, and the joint is stronger. Fine round needles should be used because they do not cut. Larger and stronger suture-material is necessary when the nerve is pierced and but two or three sutures used. After completion of the operation the parts should be so placed that the nerve is relaxed as far as possible; for example, operations in front of the wrist and in

front of the elbow require flexion; those behind the wrist and behind the elbow, extension. Muscular aponeuroses and fasciæ should not be sutured over the nerve-joint if thereby pressure is likely to be caused.

The method of peripheral **nerve-reproduction after suture** has been beautifully demonstrated by Vanlair.[1]

Vanlair cut the fibers of the internal popliteal nerve in the dog at right angles with their course; then sutured, in some cases bringing the surfaces into intimate connection, in others allowing them to remain separated by several millimeters, and again in others by a considerable distance. Sublimated silk was used in preference to catgut, the latter not offering sufficient resistance to assure a close adaptation of the segments. In performing distance suture the parts were connected by a tube of Neuber. The sutures were always passed through the epineural tissue to avoid injuring the nerve-fibers. After periods varying from eight months to several years the nerve was extirpated, hardened, and stained, after which sections were made extending from several centimeters above the section to the extremity of the nerve. The external popliteal nerve was preserved intact for purposes of comparison. The result of these experiments showed conclusively that the mode of reproduction consists in the development of new fibers, commencing above the section, pushing through the cicatricial tissue at the point of apposition, and extending to the extremity of the nerve. The course of the new fibers is not limited by the nerve-sheath, but sections made above the point of division show the new nerve-fibers pushing through outside the sheath. Sections taken at this point show, scattered among intact nerve-fibers, certain tubes containing each perhaps a half-dozen very fine fibers, each manifestly representing a young axis-cylinder. These tubes are known as "the tubes of Ranvier:" they seem to consist of a membrane which is apparently an old sheath of Schwann, thinned and distended, containing slender rudimentary axis-cylinders embedded in homogeneous protoplasm. These rudimentary nerve-fibers spring, he considers, from old axis-cylinders by fissiparous proliferation, being put forth as shoots from above the degenerated segment. These new fibers appear to be capable themselves of further subdivision and proliferation, producing thus new fibers, with the same power of multiplication. A cut 7 to 8 centimeters (2.75 to 3.2 inches) below the section shows new fibers which have acquired myelin-sheaths and appear as healthy nerves, though smaller and varying more in size than the corresponding fibers in the (healthy) external popliteal nerve.

This author shows an extremely instructive cross-section of a bony drain used to connect two separate nerve-segments. This preparation shows an Haversian canal filled with nerve-fibers in various degrees of development.

The **prognosis** in nerve-suture is good if there is a satisfactory approximation without too great tension. Complete restoration of function does not always follow, however, and in some cases there is total failure. Treatment should be continued for many months, even if there is at first little or no improvement. After a few weeks' rest for thorough healing, the limb should receive massage, passive motion, and electrical stimulation.

It has been asserted that union by first intention after nerve-suture occasionally takes place. Indeed, one case is reported in which complete restoration of function took place within the first twenty-four hours. Rapid recovery after union of divided nerve-ends suggests the establishment of collateral nerve-supply rather than the immediate transmission of nerve-force through the recently approximated cut surfaces. The restoration of function takes place, probably in all cases (though with varying speed), through the successful penetration by nerve-cells and -bundles of the cementing tissues between the united surfaces; the more aseptic, rapid, and complete the union, the earlier and more satisfactory the restoration. The reappearance of sensation takes place sooner than that of motion—a fact that goes to show that the earlier symptoms of functional recovery may be owing to collateral

[1] *Atlas der pathologischen Histologie des Nervensystems.*

innervation, which is more easily established in sensory than in motor filaments.

Neuroplasty.—When the loss of nerve-substance is so great that the ends cannot be brought together, the intervening space may be bridged either by plastic elongations of the nerve itself, or by the use of catgut, bone (decalcified or natural), nerves taken from amputated limbs, or nerves from animals. The object to be attained is the supplying between the separated ends of a medium through which the nerve-fibers may be guided from proximal to distal trunks. The simplest and best is the half-division of one or both trunks, with splitting toward and to within $\frac{1}{4}$ inch of the gap, the split ends being turned upon themselves toward each other (Fig. 422, *g*). Small gaps may be filled by thus splitting one end; larger ones, by splitting both. The elongated nerves may be joined end to end or laterally (Fig. 422, *g*). By means of this method of distance-suture long gaps may be filled. When decalcified bone is used, a piece sufficiently long is placed between cut ends and fastened there. Nerves transplanted from the lower the animals may be accurately adjusted between the divided ends and sutured. The nerve may be taken from a freshly amputated limb, or from a dog or rabbit (Fig. 422, *f*). The results following these methods are, on the whole, encouraging, though often unsuccessful. In one case the separated ends of the musculospiral nerve were successfully approximated by resecting a portion of the humerus.

Nerve-grafting.—In case it is impossible to use any of the foregoing devices, the cut nerve should be grafted upon the nearest large nerve (Fig. 425). This method can be applied only in the upper extremity, or among plexuses where large trunks are in close proximity to the divided one. The field for the application is therefore narrow. Moreover, it is rare that a single nerve like the ulnar is so extensively destroyed that elongation methods are impossible. Occasionally, however, it may be found that grafting upon another nerve is the only expedient practicable. The proximal and distal ends of the affected nerve are trimmed and sutured into the adjacent nerve-trunk, the sheath of which is first split and dissected back to receive them. The object of this procedure is to switch the interrupted nerve-stream from the proximal trunk to the selected nerve, and thence to convey it through the distal suture to its final distribution.

FIG. 425.—Neuroplasty (nerve-grafting).

The **prognosis** in nerve-grafting is by no means hopeless, although the results will never equal those of simple nerve-suture. Cases like the following, communicated to me by Roswell Park, should encourage renewed attempts in suitable cases:

"A boy of fifteen had received a gunshot injury two years previously. A charge of small shot had blown away the soft parts on the ulnar side of the right forearm below the elbow, and the ulnar nerve was destroyed. In the course of the next month contracture of flexors occurred, so that the hand was drawn to a right angle and the fingers were clawed. About

eighteen months after injury the ulnar was dissected out above the inner condyle and grafted into the median above the elbow. Its lower end was dissected out near the junction of the upper and middle thirds of the forearm and grafted into the median nerve at this level. Rather than divide all the flexor tendons to release the hand, I made an incision over each bone a little below the middle of the forearm and resected an inch from the shaft of each.

"Speedy healing of all the wounds and consolidation of the bones occurred; the hand was in good position. In ten days sensation began to return to the parts supplied by the ulnar nerve. Eighteen months later there was almost perfect sensation in the same. The boy writes well and does everything with this hand that he ever could do."

Nerve-stretching is an operation applicable to spasmodic affections of muscles—to neuralgias, tabes, neuritis, erythromelalgia, tetanus, leprosy, perforating ulcers, amputation neuromata, bone-callus neuromata, and, as an alternative procedure, to various other conditions.

Theoretically, nerve-stretching may benefit by separating adhesions between the nerve and surrounding exudates and by relieving compressions, bands, and entangling calluses. It may in some unknown way favorably affect disturbed functions, whether manifested in peripheral spasm or local pain. Stretching elongates the nerve and, presumably, affects in some way the nerve-bundles, the nerve-sheaths, the primary trunk, and possibly the nerve-roots. So far as definite results are obtained in the separation of adhesions and the relief of surrounding exudates, the procedure is scientific; so far as the results are dependent upon elongation *per se*, it is purely empirical. Recourse to nerve-stretching in painful and incurable affections of obscure etiology and pathology is justifiable; but its benefits are, to say the least, doubtful.

The nerve to be stretched is isolated in accordance with anatomical principles. It is lifted from its place with the fingers and stretched in both directions, care being taken not to break it. The amount of elongation is sometimes considerable. In nerves like the ulnar or musculospiral an inch of elongation is generally possible, a gap to that extent being easily filled by stretching and suturing divided ends.

The strength of the larger nerves is so great that there is little danger of breaking them in stretching. According to Bowlby (in Treves) the sciatic nerve will stand a strain of 100 to 160 pounds; the musculospiral, median, and ulnar, 50 to 80 pounds; other smaller nerves will carry a weight of 5 to 10 pounds. The larger nerves will therefore bear a strain fully as great as can be easily given them with the fingers. The limb can be lifted from the table, for instance, by the sciatic, when the patient is on his face. In exerting traction the breaking strain should be borne in mind, especially in the case of a nerve so important as the facial. The strength of cadaveric nerves is doubtless less than during life. Moreover, diseased nerves are often more friable than healthy ones, neuralgic trifacial trunks especially.

Stretching of large nerves like the sciatic may cause serious lesions in the cord, though in numerous experiments upon the cadaver it has been found by the writer impossible to exert any traction upon the cord by a strain sufficient to break the sciatic. Stretching of the trifacial trunks, even to complete avulsion, has never given rise to any intracranial symptoms.

An occasional result after nerve-stretching is temporary motor paralysis. This is seen in stretching of the facial nerve for spasm.

Neurotomy, neurectomy, and **avulsion** are performed to destroy entirely the functions of motor and sensory nerves. Simple division is usually sufficient to produce muscular paralysis; but is not thorough enough for neuralgias, for which removal of as much of the nerve as possible is indicated—indeed, complete avulsion in both directions. In neurotomy the nerve is exposed and divided; in neurectomy an inch or more is removed; in avulsion the nerve is grasped with hemostatic forceps and wound upon the forceps so as to separate it

from its central and from its peripheral attachments. If the nerve is grasped too strongly by the forceps it is crushed, and only that portion grasped is removed. In neuralgia the nerve is often so friable that but a small extent is destroyed by avulsion (see Neuralgia).

NEURALGIA.

Neuralgias, the most common and the most distressing of nerve-affections, demand more frequently than all others the attention of the surgeon. The operative measures at his command are stretching, cutting, and destruction of more or less of the affected trunk by neurectomy and by avulsion.

In trifacial neuralgias, by far the most common, a destruction of the affected branches as complete as possible is indicated, for milder measures are of little avail. In neuralgias of the mixed nerves, to save their motor functions, stretching is first advisable. So severe are some of these neuralgias, however, that the most extensive and destructive operations are demanded; such, for example, as amputation of a whole extremity, or division of the posterior nerve-roots within the spinal cord. The frequent and persistent neuralgias of the sciatic justify a procedure of even such doubtful efficacy as nerve-stretching.

Neurectomies in Trifacial Neuralgia.—The efficiency of neurectomies in trifacial neuralgias is well established. Unfortunately the relief following this operation is but temporary. Avulsion of the main divisions at their foramina of exit gives, as a rule, but two years' immunity from pain. Destruction of the offending filament—the inferior dental or the infra-orbital—gives about the same period of relief. It is only when the Gasserian ganglion is totally destroyed that relief becomes permanent, and the permanence of even this relief is not fully established.

In some instances, however, avulsion of the smaller nerve, to which the pain seems confined, effects a permanent cure. It seems the best plan, therefore, to attack the external nerves first affected—the supra-orbital, the infra-orbital, the mental, the buccal—in the hope of at least two years' relief. Renewed pain may then be relieved by deeper operations—upon the inferior dental by trephining the jaw or by intrabuccal dissection; upon the gustatory within the mouth; upon the infra-orbital by raising the eye and breaking out the infra-orbital canal, and by destruction of Meckel's ganglion by Carnochan's operation. Recurrence after these operations may be followed by destruction of the third division at the foramen ovale, or the second at the foramen rotundum, by lateral dissection through the temporal and sphenomaxillary fossa after resection of the zygoma. Finally, in obstinate and uncontrollable pain the Gasserian ganglion may be removed.

The gradual approach to this formidable operation thus outlined gives the patient an almost certain immunity of four or five years, and this with great safety, and with the chance of much longer immunity or even a permanent cure. The danger in the peripheral operation is trivial, the disfigurement slight. Furthermore, the period of immunity after so mild a procedure as avulsion of the infra-orbital or the inferior dental is quite as long as that after avulsion of the second and third

divisions. These peripheral operations, therefore, are not to be at once abandoned in favor of dangerous and disfiguring methods, but are rather to precede them.

Neuralgias limited to the forehead require **avulsion of the supra-orbital and frontal** branches of the ophthalmic division. The supra-orbital nerve may be isolated at the supra-orbital notch or foramen, the frontal a little to its inner side. The nerve should be grasped firmly with ordinary hemostatic forceps and twisted out in both directions. After the avulsion of this and of other branches of the trifacial there may be extensive ecchymoses.

The **infra-orbital** may be isolated and avulsed at its emergence from the infra-orbital foramen or at any point in its course under the orbit. To expose the canal, an incision is made along the lower edge of the bony orbit, parallel to the fibers of the orbicularis palpebrarum and through all the tissues to the orbital fat. The eye is carefully lifted by means of a spoon-shaped spatula; the thin-walled canal is broken open and the nerve destroyed. In some instances it is not impossible to isolate the nerve before it enters the infra-orbital canal, in the sphenomaxillary fossa. Care must be taken not to injure the infra-orbital artery, for in one case at least death has followed this accident. Avulsion of the nerve will cause hemorrhage, in spite of every precaution. The bleeding is, however, only temporary, though it may cause extensive ecchymoses.

The **inferior dental** may be found by trephining the lower jaw or by careful dissecting at the foramen of entrance. Trephining over the ascending ramus or over the angle is accomplished after separating the fibers of the masseter. The skin-incision should be horizontal, the masseter separation vertical. In one instance at least a temporary salivary fistula followed a vertical skin-cut.

Avulsion of the inferior dental, as well as of the gustatory, may be performed within the mouth. This method is desirable and efficacious, but at times extremely difficult. The

FIG. 426.—Inferior dental and gustatory nerves exposed inside the mouth (dissecting-room preparation, Harvard Medical School).

dental foramen may be exposed by an incision along the anterior and internal border of the ascending ramus. Through this incision careful dissection backward will bring into easy perception the sharp spur of the dental foramen into which the nerve and artery will be

found entering. The gustatory nerve (Fig. 426) is exposed by an incision just behind the last molar tooth. The nerve emerging from between the pterygoids passes downward, forward, and inward to the tongue, lying close to the last molar as it bends toward the tongue. It may be exposed also in the floor of the mouth by the side of the tongue. As it may be involved in cancer of the tongue, the gustatory frequently requires division. Other occasional limited neuralgias may demand the removal of single minor branches.

The **buccal nerve** (sensory) may be exposed by an incision through the cheek in front of the coronoid process. The nerve emerges just between this process and the insertion of the temporal muscle. The auriculotemporal branch of the third division is frequently affected alone. This nerve accompanies the temporal artery, and may be found by careful dissection.

In many cases a small branch of one division and a small branch of another will be affected. Under these circumstances each small branch should be avulsed if the pain is always limited to these branches. Neuralgias that shift from one branch to another, probably indicating an extensive central involvement with widely separated and transitory manifestations, demand at once the destruction of the main trunks, or even of the Gasserian ganglion itself.

These more extensive operations are indicated also by the recurrence of pain after the peripheral neurectomies. In many cases, too, the extent and the persistence of the pain require the major operation as the initial procedure.

Destruction of the main trunks is now accomplished by dissection of the sphenomaxillary fossa through the temporal region.

Destruction of the second division with removal of Meckel's ganglion may be accomplished by *Carnochan's operation*, first undertaken in 1856. The infra-orbital nerve was followed back to the ganglion by trephining the antrum, and the posterior walls of the antrum, through a V-shaped incision under the orbit. Various modifications of the operation have been practised, the object of all being to reach, with as little disfigurement as possible, the sphenomaxillary fossa. Lücke made an incision starting from a point just above the external canthus of the eye, passing backward, then downward and forward. The masseter was divided below the zygoma, and the zygoma turned back. In this way the sphenomaxillary fossa was exposed and the nerve resected at the foramen of exit. Lossen cut the temporal fascia and turned the masseter back with the zygoma. Nussbaum in 1863 and Billroth in 1864 reached the nerve by doing Langenbeck's osteoplastic resection of the superior maxilla. Reyher first tied the carotid and then performed Lossen's operation. Wagner made an incision below the eye, and with the eye raised out of its bed followed the infra-orbital nerve back to the foramen rotundum. Gerster turned back a section of the malar bone, and in that way reached the sphenomaxillary fossa.

Excision of the third division of the fifth nerve was first performed about twenty-five years ago by Pancoast of Philadelphia, who raised a cheek-flap with its base at the zygoma, sawed through the zygoma, and turned it down with the masseter muscle. The coronoid process was excised and the temporal muscle turned up. *Krönlein's operation* was similar, but his flap was turned downward from the top of the zygoma, and the coronoid process upward with the temporal muscle. In 1887 or 1888 Salzer made a larger flap, with its base at the zygoma. The temporal fascia and muscle were separated from their attachments and turned down with the zygoma. In 1891 Mixter combined the two operations of neurectomy of the second and third divisions by exposing first one and then the other foramen, after dividing the temporal muscle.

Carnochan's operation may be employed in suitable cases—cases in which the pain is confined exclusively to the second division and its branches. A V-shaped incision, with its apex downward, is made about ½ inch below the infra-orbital foramen. A sharp-pointed bistoury is thrust through the cheek into the mouth from the apex of the incision, and carried downward through the cheek to a point midway between the angle of the mouth and the center of the lip. The flaps thus formed are turned, one upward, another backward, and a third forward, exposing the bony anterior surface of the superior maxilla. An opening, with its center a little below the infra-orbital foramen, and from ½ to ¾ of an inch in diameter, is then made in the anterior wall with a trephine or chisel. Next, an opening of ¼ to ½ of an inch is made in the posterior wall. The groove of the infra-orbital nerve is opened from the antrum and the nerve followed back to the foramen rotundum, where the second division is divided with a blunt-pointed pair of scissors. The operation is unnecessarily disfiguring, yet in its main points it is still used.

In view of the generally admitted necessity of thoroughness in operations upon trifacial neuralgias, and especially upon neuralgias intermittently affecting widely separated filaments, now of the second and now of the third divisions, the more extensively destructive operations seem to grow in favor. Exposure of the sphenomaxillary fossa in avulsion of the third division by Lossen's operation was followed by **Mixter's operation** of avulsing both second and third divisions through the same incision. This operation, as understood and performed by the author, is as follows:

The principal anatomical feature in this operation consists in the exposure of the foramen rotundum and the foramen ovale by section or displacement of the temporal muscle. The first step consists in removal of the zygoma. A curved incision, with its base at the zygoma and its convexity upward, is made from the external margin of the orbit to the lobe of the ear. The ends of the cut must go ½ inch below the zygoma. The zygoma itself is then sawed in front and behind, the cuts being slightly bevelled from without inward, and care being taken to avoid opening the articulation of the lower jaw. To permit satisfactory replacement, the fat and fascia attached to the zygoma are removed with it. The zygoma, with the masseter and other attachments, is now pulled downward, the temporal muscle being thus exposed. If the operator is skilled enough in the subsequent manipulations, he may omit the cutting of the temporal muscle. Should he require a good deal of room, he may divide the muscle transversely and follow the bone directly to the foramina, being guided entirely by the sense of touch. The most desirable method, because the least destructive and the least disfiguring, is that of leaving everything intact after cutting the zygoma, and proceeding to the second division in front of the temporal muscle, and then to the third behind that muscle. The guide to the foramen rotundum and the second division is a spur of the great wing of the sphenoid; to the foramen ovale, the base of the pterygoid

FIG. 427.—Retractor for deep operations on the second and third divisions, fifth nerve.

plate of the sphenoid. To approach the foramen rotundum, the zygoma is pulled downward, the temporal muscle backward. Retractors of special construction aid in exposing the deep parts (Fig. 427). The most desirable attributes of the retractors are sufficient depth, breadth, and smoothness, to give a clear view without lacerating veins. The spur on the great wing of the sphenoid is quickly exposed. If prominent and in the way, it may be chiselled off, care being taken not to open the middle fossa. By this time the anterior field will be so bloody that it must be packed with gauze. The retractors are therefore shifted to the field behind the temporal muscle. The chief points about the foramen ovale are (1) that it is situated at the base of the pterygoid plate, and (2) that it is about 1¼ inches internal and a little posterior to the anterior margin of the posterior attachment of the zygoma. The index finger is worked inward and slightly backward, starting from the base of the zygoma, until the base of the pterygoid processes is reached, where the foramen can be usually recognized by the sense of touch (Fig. 428).

In penetrating to the foramen ovale the pterygoid muscles may be disregarded. They yield readily to the fingers or to the retractors; they are but slightly injured, and their functions are subsequently unimpaired. If the temporal muscle is cut, and the pterygoids with their attachments to the skull are extensively lacerated, their impairment, as well as that of the temporal muscle itself, is considerable, and movements of the jaw are often limited. As soon as the depths of the wound are visible, after the retractors have been carefully and deeply placed with reference to the situation of the foramen, the zygoma, and the pterygoid base, the nerve will often be visible. Should it be still obscured, its position may be sought by repeated thrusts of the right-angled hook (Fig. 429), by careful searching with the blunt dissector, or by following down a motor filament from the coronoid notch. Some-

times the nerve will be found separated into two parts by a spur of bone close to the foramen.

In many cases the application of the retractors will cause rupture of veins and even of

FIG. 428.—Third division at foramen ovale: temporal muscle drawn forward.

arteries, with free hemorrhage. The field must then be packed with gauze. In the meantime the retractors may be shifted to the anterior field, which will be found perfectly dry.

FIG. 429.—Nerve-hook.

The second division will be found just in front, and to the inner aspect, of the base of the spur previously removed. It may be easily grasped by means of a suitable hook (Figs. 430,

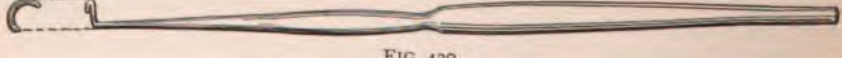

FIG. 430.

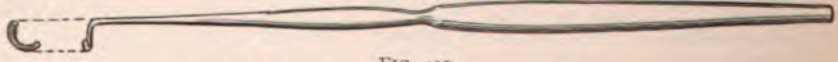

FIG. 431.

FIGS. 430, 431.—Instruments for hooking up nerves.

431), and drawn out enough for the application of strong hemostatic forceps, by means of which it is forcibly avulsed (Fig. 432). The anterior wound is again packed with gauze, and, if necessary, renewed search is made for the posterior division. The nerve, if not seen, may be

hooked up by means of suitable instruments passed about the position of the foramen ovale, as demonstrated by the finger or the right-angled hook. When recognized, it should be grasped by hemostatic or other suitable forceps and slowly avulsed in both directions. The motor branches of the third division should, if possible, be avoided. As a matter of fact, they are always destroyed. The posterior wound is then packed with gauze for hemostasis;

FIG. 432.—Operation on second division, fifth nerve, in sphenomaxillary fossa: temporal muscle drawn backward.

the anterior gauze is removed. As soon as the oozing has ceased the zygoma is stitched into place and the wound closed. If oozing is considerable, a gauze wick may be left from twenty-four to forty-eight hours.

If the temporal muscle is divided, there will be more room, and the nerve will be more easily found. It will be necessary, however, to suture the muscle, and the deformity and muscular impairment will be greater.

The operation as described above is at times very difficult, chiefly on account of hemorrhage. However familiar the surgeon may be with the anatomy of the parts, he will find it extremely useful to have a skull at hand for reference.

After even so extensive a destruction of nerve-trunks there will often be for a day or two complaint of pain in the course of the avulsed nerve. This will soon subside, however, and relief will be complete.

Removal of the Gasserian Ganglion.—Removal of the Gasserian ganglion should not be performed in feeble patients or in those suffering from serious diseases, for the danger of the procedure is great.

Two methods are used—that of Rose and that of Krause-Hartley. *Rose's method* consists in exposing the skull deep in the temporal fossa by displacing the zygoma downward at and external to the foramen ovale. A trephine opening is made, through which the third division is followed to the ganglion. Removal of the ganglion is accomplished piecemeal

by means of suitable instruments. The chief objections to this method are that it is very difficult to see what is being done, that hemorrhage is hard to control, and that serious injury may be caused to important structures.

The *Krause-Hartley method* (Fig. 433) consists in removal of a portion of the skull at the temporal fossa sufficiently large to permit the full recognition and intelligent isolation of

FIG. 433.—Dissection showing Krause-Hartley operation on Gasserian ganglion.

the ganglion and its technically perfect removal without injury either to the cranial sinuses or the motor nerves. The application of this method, as practised by the author, is as follows: A curved incision, with its convexity upward, is made above the zygoma of the affected side. A section of bone similar in shape to the skin-flap, though somewhat smaller, is next cut from the squamous portion of the temporal and the greater wing of the sphenoid. The upper convex portion of the bone-cut must first be made with a saw, as in bone-flap exposures of the motor areas. The base of the flap must then be broken by prying outward and downward. Unless the basal attachment is comparatively narrow, the line of fracture will be uncertain. It may break at the line desired, or it may extend far inward toward the body of the sphenoid, rupturing the middle meningeal artery or even the cavernous sinus. It is probably a better plan, on the whole, to remove first a small button with the circular trephine, and from this opening to separate carefully the dura and enlarge sufficiently with the rongeur forceps. The extent of bone to be removed will vary with the difficulites of satisfactory inspection, the amount of hemorrhage, and the displaceability of the middle lobe. The base of the opening should in most cases extend from a point just above the external auditory meatus to the tip of the lesser sphenoidal wing.

The dura mater and brain are next separated from the middle fossa toward the tip of the petrous bone. In some instances this may be accomplished without opening the dura; in others the dura is torn in all directions. Separation of the dura may be brought about by means of the finger, a blunt instrument, or a piece of gauze (Tiffany). Hemorrhage is usually slight. In case the middle meningeal artery is injured, it should be tied as near the foramen spinosum as possible. In many instances it will be impossible to avoid tearing this artery, and very difficult to tie it, because it will be found deeply placed in a bony groove, in a part of its course at least. Lifting the dura will tear the artery; its position in its groove will prevent ligation. Under these circumstances the wound must be packed tem-

porarily before proceeding with the operation. In some cases further manipulations will be impossible at the time, and the operation will require two stages. A general ooze may be checked with gauze. An open sinus, compressed with the fingers for a few minutes, will usually cease bleeding. Hemorrhage may be so abundant and persistent, however, as to require prolonged gauze packing, or even ligation of the external carotid.

If the dura cannot be easily separated from the middle fossa, if it is extensively torn and the brain exposed, further attempts at separation should be abandoned. Intradural manipulations, though perhaps more dangerous than extradural, have the advantage of being intelligently directed with reference to the chief dangers of the operation—wounding of the cavernous sinus, laceration of the brain, and wounding of motor nerves to the eye. Moreover, by this method the nerve-roots entering the ganglion may be divided between it and the pons, as Horsley has demonstrated. Finally, there is but little danger of tearing the middle meningeal artery near the foramen spinosum.

As soon as hemorrhage has ceased, the brain should be carefully lifted from the middle fossa by means of a broad, curved spatula or by the fingers of an assistant. In the intradural operation the ganglion may be started from its bed by cutting and lifting the second and third divisions as they enter their respective foramina. Perhaps the most efficient plan is to divide the third branch close to the foramen ovale, the second at the foramen rotundum, to dissect the two backward, separating them from their attachments. The ophthalmic nerve may then be separated from its contiguous structures and cut at the sphenoidal fissure. This separation must be made with extreme nicety, to avoid injuring the cavernous sinus and the motor nerves of the eye. The advisability of removing the ophthalmic division is questioned on account of the trophic changes likely to follow in the eye, and because the first division is never affected alone, though it may be involved reflexly.[1]

The motor root of the fifth division should be left intact if this can possibly be accomplished. The distal attachments of the ganglion having been separated and the ganglion lifted from its bed, the connection with the brain should be severed close to the dura mater. If the dura mater has been opened, the filaments connecting the ganglion with the pons may be divided, though this will destroy the motor trunk. If there is oozing after reasonable delay in packing in the depth of the operative field, a small gauze wick should be left for twenty-four or forty-eight hours. In some instances there will be so much hemorrhage that the depths of the wound will require packing.

The immediate dangers of the operation arise from hemorrhage and shock; remote dangers are meningitis and superficial abscess. A disagreeable, not unavoidable feature is the trophic change liable to occur in the eye of the affected side, with loss of sight.

As a relief from the distressing pain of a trifacial neuralgia, this operation gives better and more lasting results than any other. Because of its dangers and disadvantages, however, it is justly characterized as the "operation of last resort." According to Tiffany[2] the mortality was 24 in 108 cases—22 per cent.—the chief causes of death being shock (8 cases) and sepsis (8 cases). "Relief of pain certainly follows temporarily, and sometimes permanently; but it may recur" (Tiffany).

Neuralgias affecting the brachial plexus or its branches occasionally cause obstinate and unbearable pain. An ascending neuritis starting in a peripheral branch and finally involving the brachial plexus may have required successively stretching or avulsion of the branch originally affected, stretching of the brachial plexus, amputation of the hand, of the forearm, of the upper arm, or even of the arm at the shoulder. According to Abbe,[3] such neuralgias may accompany an ascending neuritis, a hemiplegia, herpes zoster, and allied conditions, as well as carcinomata. They may start in the bulbous ends of nerves or in amputation stumps. For the unbearable pain the affected nerves have been stretched, excised, avulsed, the extremity amputated. Even these drastic measures often fail. As a last resort the posterior nerve-roots may be divided within the spinal dura.

[1] *Annals of Surgery*, 1896, vol. xxiv., p. 584.
[2] *Annals of Surgery*, 1896, vol. xxiv., p. 585.
[3] *Boston Med. and Surg. Jour.*, Oct., 1896, p. 329.

Abbe's[1] method of dividing the posterior nerve-roots is as follows: "The region from which the affected nerves make their exit from the cord having been determined, a long incision is made on one side of the spinous processes, the incision being carried rapidly down to the laminæ. The spinous processes are next cut through at their base with bayonet-shaped cutting pliers, leaving the interspinous ligaments intact. These processes, with the muscles attached, are retracted well to the other side. The laminæ are then gnawed away with rongeur forceps from the transverse processes to the base of the spinous processes. The dura is exposed and opened the full length of the incision, allowing about 2 or 3 drams of cerebrospinal fluid to escape. The cord is then pulled to the side of the canal, and the roots picked up by a blunt hook. From ¼ to ½ inch of nerve is excised. The dura is sutured with fine catgut, and the muscles allowed to fall back into place." Keen advises destruction of the ganglion also.

Neuralgia of the Lower Extremity.—Painful affections of the lower extremity may be treated like those of the upper extremity. In the event of failure the distressing symptoms may require division of the posterior nerve-roots in the lumbar or the sacral portion of the cord.

Neuralgias dependent upon injury, upon the contraction of cicatricial tissues, upon entanglement in new growths, may affect any sensory nerve. The surgical treatment is the same as that already outlined—disentanglement from the exciting cause by stretching, neurectomy, removal of the tumor or of the cicatrix.

Neuralgias involving nerves or groups of nerves other than those considered above are met with occasionally. The same principles of treatment apply (see Special Nerves).

MUSCULAR SPASM.

The surgical treatment of muscular spasm is chiefly that of **spasmodic wry-neck.** The etiology of this obscure affection is so uncertain that treatment, in the absence of definite indications, must be symptomatic. Spasmodic wry-neck demands surgical intervention only when all rational palliative methods, such as rest, fixation, massage, gymnastics, electricity, and drugs, have failed. The results of operation upon the spinal accessory nerve, of neurotomy and neurectomy, of nerve-stretching and nerve-avulsion, are on the whole encouraging—the more destructive the operation, the more lasting the benefit. Unfortunately, the immediate quieting of the sternomastoid and the trapezius—the muscles chiefly affected—is followed in many cases, sooner or later, by spasmodic contractions of the posterior rotators of the head on the opposite side. In the majority of cases, therefore, operation upon the spinal accessory nerve must be followed by operation upon the nerves supplying the posterior rotators.

In the simplest form of spasmodic wry-neck the head is tilted forward and rotated by the sternomastoid. In the common extension of spasm to the posterior rotators of the other side previously mentioned, rotation occurs in the same direction, but the head is drawn back rather than tilted forward, through the greater power of the posterior rotators, which are also retractors. In exceptional cases the head is drawn directly backward by the posterior muscles of both sides acting simultaneously (*retrocollis*). In a still rarer form the head is drawn directly forward by the combined action of the two sternomastoids. An occasional instance is seen of combined action of the sternomastoid of one

[1] *Boston Med. and Surg. Jour.*, 1896, vol. cxxxv., p. 329.

side with the posterior rotators of the same side, the head being in this event drawn directly toward the shoulder. In many cases the spasm can be controlled by continuous effort; in others it is beyond control. The spasm may recur constantly and violently or infrequently and mildly. Though palliative treatment may afford relief, many cases yield only to operation. (For the etiology, the symptomatology, and the medical treatment, the reader is referred to works upon Neurology.) The muscles affected can be determined by the position of the head and by palpation during the spasm. The sternomastoid and the trapezius will be seen in spasmodic action of varying frequence and violence.

Operations on the Spinal Accessory Nerve.—The spinal accessory nerve can be exposed best at the point at which it crosses the upper part of the neck before entering the sternomastoid. It proceeds downward and outward from the jugular foramen, and first touches the anterior border of the sternomastoid at a point about ¾ inch or more below the tip of the mastoid process. An incision from 1 to 2 inches in length should be made along the upper part of the anterior border of the sternomastoid. The dissection is carried directly backward toward the vertebral bodies. The nerve lies more or less concealed in fascia, but can usually be seen if the dissection is bloodless. Its position may be felt by drawing the end of a scalpel handle or the finger nail downward over its probable position. As the instrument or the nail snaps over the nerve the sternomastoid and trapezius will contract. Once isolated, it may be stretched or divided, resected or avulsed. The most satisfactory method is to remove at least an inch of it. The wound heals rapidly, and the immediate effect of the operation is generally favorable.

In many cases the spasm is not immediately relieved, though the sternomastoid and trapezius are at once relaxed. As an accessory aid the head may be immobilized for a few days after the operation. In many cases, however, the spasm appears in other groups of muscles, usually the posterior rotators of the other side.

Of the **operations upon the posterior rotators, Keen's operation,**[1] based entirely upon anatomical lines, seems to be the most satisfactory. The following description is taken from Keen's article:

The first step in the operation consists in a 3-inch incision across the neck, starting from the median line, at a level ½ inch below the lobe of the ear. This incision is carried through the trapezius and posterior border of the splenius capitis. The trapezius is then dissected free from the complexus, above and below, until the intramuscular aponeurosis, usually ½ inch below the incision, is found. The occipitalis major is usually found between this aponeurosis and the median line. The complexus is now divided, following the occipitalis carefully as a guide. This nerve is freed to its origin from the second cervical nerve. A section of the trunk of the posterior division of the second cervical nerve, between the occipitalis major and the spine, is removed in order to reach the filament from this region to the inferior oblique muscle. Next is found the inferior oblique muscle, to which the *occipitalis nerve* is a guide as it swings around the lower border of it. Above this muscle is the suboccipital triangle, in which the suboccipital nerve will be found close to the occipital bone and in close proximity to the vertebral artery.

Again starting from the occipitalis major and dissecting up the complexus, the external branch of the posterior division of the third cervical nerve will be found about 1 inch below. This nerve is to be divided close to the main trunk and a piece excised. If it is desired, the muscles can now be sutured with buried catgut sutures. The wound is then closed.

It is not essential, however, to suture the divided muscle; for the very division of the muscles is quite as important, at least in some cases, as the division of the nerves. In one instance the writer divided not only all the nerves mentioned above, but also every muscle from the external occipital protuberance to the sternoclavicular joint. In this case a perfect cure resulted, although the spasm had been excessive and accompanied by permanent shortening of the whole group, with marked lateral deformity (the author).

Other muscular groups may be the seat of spasm. (For the consideration of these the reader is referred to Special Nerves.)

[1] *Annals of Surgery*, 1891, vol. xiii., p. 44.

NERVE-TUMORS.

Neuromata, single or multiple, are not uncommon. True neuromata composed of nerve-tissue are extremely rare, but have been observed. Tumors made up of other than nerve-tissue are not infrequent. Such neoplasms may be intimately incorporated with the nerve-

FIG. 434.—Neuroma after amputation. At the right are normal nerve-fibers passing into a bulbous enlargement containing some myelin-fibers and much connective tissue (stain, Weigert; oc. 1, obj. 1, Leitz). (From specimen supplied by E. W. Taylor.)

bundles or they may be loosely attached to them. The most frequent are the fibromata (Figs. 434, 435); sarcomata (Fig. 436) and myxomata

FIG. 435.—Nerve-neuroma. Rounded tumors connected with the nerve-trunks close to their cut ends. Man aged eighteen. Amputation of arm nine years before. Severe pain. (Warren Museum, Harvard Medical School.)

are occasionally seen; but carcinomata, gliomata, and degeneration cysts are very rare. In the multiple neuromata the tissue is usually fibrous, though there may be other and malignant forms; moreover, different varieties, benign and malignant, may exist in the same individual.

The **symptoms** of neuromata vary. First there is usually pain along the course of the affected nerve. The nerve-functions become interfered with and impaired. Anesthesia, loss of power, and complete cessation of function, with trophic changes, may ensue. The tumor

FIG. 436.—Sarcoma of sciatic nerve; resection, neuroplasty; restoration of function almost complete; no recurrence up to 1899; sciatic nerve excised (Richardson).

is painful, sensitive, and moves laterally rather than longitudinally, on account of the nerve-attachments. In multiple fibromata the brain and spinal cord, the cranial and spinal nerve-roots, the ganglia, the plexuses, and the peripheral trunks may be more or less extensively involved. Widely separated trophic changes, interferences with nutrition, bed-sores, and fatal marasmus follow in more or less regular sequence.

Treatment.—For single neuromata excision is the only rational treatment. In benign neoplasms this operation may be delayed; in malignant, it should not be delayed. The impossibility of exact diagnosis requires, however, exploration at once—of benign neoplasms, for the relief of symptoms that can be relieved in no other way; of malignant, chiefly to save life. Benign neoplasms not intimately caught among nerve-trunks should be dissected out with as little injury to the nerve-bundles as possible. If separation is impossible, the nerves should be cut above and below the growth, the growth removed, and the nerve-ends united. Before cutting the nerve, it should be thoroughly stretched. Malignant tumors involving nerves should be removed by complete nerve-section, unless their connection with nerve-trunks is such that thorough dissection is possible. Encapsulated sarcomata, incorporated with important nerves, but easily separated from the nerve-bundles, may be carefully removed. In cases of doubt the nerve and tumor should be resected. When several accessible

tumors exist, involving one or more nerves, all may be excised. The usual form of multiple neuromata admits of no surgical treatment.

Bulbous nerves in amputation stumps are composed chiefly of fibrous tissue, in which the nerve-bundles may become compressed, giving rise to pain. In some instances an ascending neuritis may follow, and require section of the posterior nerve-roots. The bulbous ends can generally be felt in the amputation stump as painful, tender tumors. They should be dissected out and excised with the knife, after stretching of the nerve to which they are attached. For the same reason that they first appeared, they are likely to recur in the same individual. It is important in amputating to avoid including in the ligature of arteries the nerve or any of its filaments, especially if a non-absorbable ligature is used. Though it has not been demonstrated that compression of a cut nerve-end by a non-absorbable ligature is a cause of bulbous nerves, yet the possibility of such causation should be borne in mind and the contingency avoided.

LESIONS OF SPECIAL NERVES.

Injury to the olfactory nerve, by fracture through the cribriform plate of the ethmoid, may result in permanent impairment of the sense of smell.

The **optic nerve** may be compressed by retrobulbar neoplasms or by inflammatory exudations. Impairment of sight may gradually follow excessive pressure, the nerve successfully withstanding extraordinary elongation or elevation. Fracture through the lesser wing of the sphenoid may destroy completely the functions of the nerve. Pressure from orbital tumors and exudates should be relieved, if possible, by dissection or by drainage. The orbital cavity may be approached by removal of the external angle of the frontalbone. When the nerve has been ruptured by fracture, nothing can be done.

The **third, fourth,** and **sixth nerves,** from their course along the cavernous sinus, may be involved in fractures of the base of the sphenoid; they may be compressed by new growths; they may be wounded during operations upon the Gasserian ganglion. Accidental wounding of the nerves by operation has not, however, been recorded. Nevertheless, intracranial dissection of the ganglion should be made with great care, to avoid these important structures.

Affections of the **fifth nerve** have already been considered.

The **auditory nerve** may suffer through fractures or wounds of the petrous portion of the temporal. A case has recently come under the author's observation in which an accidental gunshot-wound, piercing the meatus, destroyed entirely the sense of hearing. Whether this was owing to injury to the structures of the middle ear it was impossible to say. Removal of the bullet was not followed by any improvement in hearing.

The **facial nerve** may be injured anywhere in its course through the temporal bone. It is peculiarly liable to injuries during operations upon the face. Facial paralysis following severe injury to the skull always suggests a fracture somewhere through the temporal bone, with bruising, laceration, or total destruction of the nerve. A facial paralysis accompanying inflammation of the middle ear portends extension of the process into the mastoid cells, or at least pressure of an exudate somewhere in the course of the nerve, either as it crosses the vault of the tympanum or in the mastoid itself. This nerve is also involved in certain neoplasms of the parotid, especially infiltrating carcinomata. The nerves, strangled by the density of the growth, may be found infiltrated with cancer cells. In this form of facial paralysis the compression comes on gradually. It is total, and, from the nature of the surrounding tumor, cannot be successfully relieved; for it is essential in such cases, if any attempt is made at thorough removal, to take out the whole growth

by as wide a margin of sound tissue as possible, and in this dissection the nerve is, of course, sacrificed. Acute parotitis may, though infrequently, cause facial paralysis. The facial nerve is perhaps more frequently associated with muscular spasm than any other, excepting the spinal accessory. Whether the nerve merely transmits the central irritation, or is itself the seat of irritation, cannot be determined any more positively than in spasmodic wry-neck.

Treatment of Facial Paralysis.—No surgical treatment is possible except stretching of the nerve. The nerve is exposed at the anterior border of the parotid or in the parotid itself. If but one division is affected, the nerve may be sought in front of the parotid; if the whole nerve, it may be exposed in the parotid gland, about a finger's breadth below the lobule of the ear. It may be exposed behind the parotid, between the sternomastoid and the stylomastoid foramen, according to Bonner's method. By this method the resulting scar is inconspicuous. The nerve may be stretched upon the finger as upon a bent hook. It will bear, post mortem, between 5 and 10 pounds; but less force should be used in life.

Facial paralysis occurring suddenly in persons of good health, usually supposed to be owing to the effect of cold or exposure, is probably caused by pressure, either postural during sleep, or from some other source.

The treatment of facial paralysis from the causes mentioned is discouraging. Nothing surgical can be done for these paralyses dependent upon causes within the bony canal, unless they are produced by inflammatory exudations in the mastoid, in which case they may be relieved by trephining and drainage. Paralysis caused by the constriction of new growths gives little hope of relief, unless the growth is benign, when the nerve may be dissected out of the growth. In carcinoma such a method of relief is impracticable. Tumors that do not surround and constrict the nerve rarely, if ever, cause trouble. The commonest tumor of the parotid—the enchondroma—may attain enormous size without affecting the nerve-function. More paralyses result from cutting the nerve in removing these large growths than occur in the natural development of them.

The facial may be exposed in the mastoid by chiselling, in those rare instances in which such an operation is desirable. It may be isolated at the stylomastoid foramen and followed back through the aquæductus Fallopii.

The **glossopharyngeal nerve** has no surgical importance, though frequently paralyzed as the result of diphtheria; and though, like all other nerve-structures, it may be injured, its situation gives it no especial surgical interest.

The **pneumogastric nerve** may be involved in neoplasms of the neck; it may be compressed or dislocated by them; it may be compressed in deep cervical abscess; it may be divided in deep wounds of the neck; it may be injured accidentally in deep operations upon the neck; or it may be deliberately resected in the removal of infiltrating cervical tumors. The symptoms caused by section of the vagus vary. In cases collected by Park,[1] dyspnea, dysphagia, slow respiration with

[1] *Trans. Am. Surg. Assoc.*, vol. xiii., p. 253.

laryngismus and alteration of voice, reduced respiratory murmur of the affected side, asthma, pneumonia, etc., were observed. When both pneumogastric nerves were affected by the pressure of tumors, there were present lung-disturbances, dyspnea, depression of pulse, and ravenous appetite. In 48 cases in which the nerve was cut, 21 died and 27 recovered. In the fatal cases it was impossible to say that death was caused by the lesion alone.

Section of the pneumogastric does not necessarily mean death; but operation should not be prolonged after division, and the nerve should, if possible, be immediately sutured. The pneumogastric nerve may be exposed by a longitudinal incision in the neck. It will be found behind and between the carotid artery and the jugular vein, in the same sheath with them.

Affections of the **recurrent laryngeal branch** of the pneumogastric nerve are more frequent than those of the trunk. This nerve, on one or both sides, is occasionally involved in tumors—malignant, benign, or aneurysmal—of the deep neck, or of the mediastinum, of the esophagus, the trachea, or the thyroid. It may be injured by the impaction of foreign bodies in the esophagus, or compressed by deep cervical abscesses; it may be injured in the removal of thyroid tumors or in the ligation of the inferior thyroid arteries. Paralysis of the recurrent laryngeal nerve results in interference with the voice, in spasm of the glottis, and in dyspnea. Symptoms of recurrent laryngeal involvement may aid in the diagnosis and localization of tumors and foreign bodies. The results of such involvement may produce the most alarming symptoms of impeded inspiration, and may require immediate tracheotomy.

The **treatment of laryngeal spasm** requires tracheotomy or intubation, after relief of the dyspnea by operation upon the recurrent laryngeal and removal, if possible, of the compressing tumor. In the case of pressure by a deep cervical abscess or by a foreign body, the abscess should be opened or the foreign body removed. In many instances the effects of pressure or of irritation are transitory; in others they are permanent.

The **spinal accessory** may require surgical treatment in connection with spasmodic wry-neck; it may be injured accidentally; it may be removed or resected in the removal of tumors deeply situated under or beyond the mastoid. The cutting of this nerve produces no serious symptoms. The muscles supplying the sternomastoid and trapezius soon regain their tone through collateral branches of the cervical plexus or of the spinal nerves.

The **hypoglossal nerve** may be injured by gunshots, cuts in the throat, and in operations upon submaxillary tumors. The division of this nerve produces a deviation of the tongue to the side. It is removed in resections of the tongue. The writer has removed portions of this nerve in operations upon infiltrating tumors at the submaxillary triangle without serious impairment of the movements of the tongue. No surgical intervention is necessary in affections of this nerve, except that in simple division of the nerve, accidental or intentional, the cut ends may be united, as described under Nerve-suture.

The hypoglossal nerve may be exposed through a curved incision along the lower border of the submaxillary triangle. It will be found, as it passes under the mylohyoid, in close relation with the lingual artery.

Cervical Plexus.—Of the cervical plexus the **phrenic nerve** is most important from the surgical point of view. The nerve may be

injured in operations and accidental wounds of the neck. Its position with reference to the scalenus anticus muscle should be carefully borne in mind in deep cervical dissection. The symptoms are not usually immediate; they are interference with respiration, incessant coughing, purulent bronchitis, congestion of the lungs and pneumonia. Of 8 cases collected by Park,[1] 2 recovered. In the recoveries it is not clear that the phrenic was actually divided. Accidental division should be followed by immediate suture.

Other branches of the cervical plexus may be wounded, and often are wounded in dissection of the neck. They should be avoided as much as possible in such dissection, though when thoroughness requires it, they may be freely sacrificed. The chief objection to the cutting of these nerves is an anesthesia which, though but temporary, is unpleasant, and an occasional neuralgia from entanglement with the scar.

The **brachial plexus** may be injured by direct violence, cuts, stabs, by pressure upon the exostosis of the first rib, by pressure of a cervical rib, by the pressure of tumors, by the immediate bruising from dislocation of the head of the humerus, or from the pressure of crutches. In incised wounds the cut ends of the cords of the plexus should be united, if possible; pressure from tumors or exostoses or the other causes enumerated should be relieved. The cords of the plexus may be exposed by deep dissection of the subclavian triangle.

The **circumflex nerve** has special importance from the frequent paralysis of the deltoid caused by falls upon the shoulder. Such paralyses, however, usually recover, and spontaneously. Massage, passive motion, and electricity aid in restoring the functions of the nerve.

The **musculospiral nerve** is most frequently affected by fractures of the shaft of the humerus. It may be either lacerated or contused at the time of the injury, or, later, may be caught or pressed upon in the resulting callus. This nerve, more than any other in the body, is likely to be the seat of serious traumatic lesion. The nerve is exposed by an oblique incision over the musculospiral groove by cutting through the tendon of the triceps. If it is not readily found, a branch of the superior profunda artery should be followed up to the main trunk, which will be found running parallel to the nerve.

The **musculocutaneous nerve** may be injured in operations about the shoulder-joint or the axilla, before it enters the biceps. Injuries to this nerve produce paralysis of the biceps and the brachialis anticus. In venesections of the median cephalic at the elbow the nerve may be directly injured, or irritated and rendered painful by the pressure from the resulting scar.

The **ulnar** and **median nerves** in the upper arm are sometimes divided; sometimes they are pressed upon by tumors, and sometimes by the prolonged application of the elastic tourniquet. The ulnar may be injured in excisions of the elbow-joint. The median nerve will be found by an incision parallel to the brachial artery, along the edge of the biceps and coracobrachialis; the ulnar, above the middle of the arm, will be found at the inner side of the brachial artery.

The **ulnar nerve at the wrist** is more commonly injured than any

[1] *Loc. cit.*

other nerve; the median less commonly than the ulnar. Injuries to this nerve at the wrist are usually the result of incised wounds from accidents. The ulnar nerve is not infrequently injured in fractures of the elbow involving the internal condyle. Temporary paralysis may follow long-continued pressure at this point. It may be exposed in the groove behind the internal condyle. From the elbow to the wrist it should be sought by reference to its relation to the flexor carpi ulnaris.

The **median nerve** may be exposed at the bend of the elbow, where it lies in close relation to the brachial artery; between the bend of the elbow and the middle of the wrist it lies between the superficial and the deep plexus, the guide to it at the wrist being the tendon of the palmaris longus. If that muscle be absent, it may be found lying superficially among the flexor tendons.

Wounds of the **branches of the ulnar and median nerves in the hand** are not infrequent. Unless the lesion is at a point central to the distribution of the muscular branches, no operative intervention is indicated. In some instances, however, section of the terminal sensory branches may cause unpleasant symptoms and may justify suture. Two instances of this kind have come under the writer's observation; both were relieved by operation. The posterior interosseous branch of the musculospiral may be injured in serious lesions of the elbow-joint and in operations for excision. This nerve may be avoided by giving the supinator brevis a wide berth. In several cases of fracture of the lower end of the humerus, wrist-drop has been caused by a lesion of the posterior interosseous branch, the radial being uninjured.

The **intercostal branches of the spinal nerves** are sometimes, though rarely, the seat of neuralgias. A persistent intercostal neuralgia suggests the pressure of a thoracic aneurysm. True neuralgia limited to the nerve, not associated with mediastinal tumors, may justify excision of the main trunk of the affected nerve. This may be done by an incision into the intercostal space, near the middle of which the nerve usually lies. The intercostal and other nerves supplying the abdominal muscles may occasionally require stretching or section for abdominal spasm. One such case has occurred in the writer's experience.

The **nerves of the lumbar plexus**—the ilio-inguinal, iliohypogastric, external cutaneous, and genitocrural—have a passing interest. Traumatic lesions are usually operative, though they may be accidental. The ilio-inguinal or the iliohypogastric may be compressed by the sutures applied in operations for movable kidney. This nerve in its course passes along the border of the quadratus lumborum. In one instance at least the writer has met with a most painful affection of this nerve from entanglement in the fixation-ligatures of a nephrorrhaphy. The ilio-inguinal and the iliohypogastric may also be injured in operations about the inguinal canal and spermatic cord. Neuralgia of the testicle, in some instances, at least, may be relieved by neurectomy of the ilio-inguinal or the genitocrural branches to the scrotum and testis. Such an operation should be tried for the relief of pain before orchidectomy is resorted to.

The **nerves of the lower extremities** may be the seat of serious traumatism, accidental or operative. They may require the same

general principles of treatment as the nerves above mentioned. The **anterior crural nerve** and its branches can be exposed by a longitudinal incision beginning at the middle of Poupart's ligament. The nerve is external to the artery, and breaks up to supply numerous muscular branches. The chief sensory branch—**the long saphenous**—passes downward over the internal condyle of the femur, and is distributed over the inner side of the foot. It may be exposed anywhere along its course.

Of the sacral plexus the **sciatic** has the greatest importance from its being frequently the seat of intractable pain. From the great importance of this compound nerve, neurectomy is inadvisable, and stretching has frequently been applied. It may be exposed in the posterior region of the thigh, just below the lower border of the gluteus maximus (see Nerve-stretching). A stretching force sufficient to lift the thigh from the table may be applied, the patient being prone.

The **popliteal nerves** may be the seat of painful affections from the pressure of popliteal tumors, especially aneurysms. Relief is obtained by removal of the tumor or by cure of the aneurysm.

The anterior tibial may be injured as it passes round the head of the fibula, being there subcutaneous. This nerve may be exposed by an incision through the skin at this point. Further down it can be found between the tibialis anticus and the extensor longus digitorum. High up in the anterior region of the leg, it lies between the extensor pollicis and the tibialis anticus.

The **posterior tibial** may be exposed by section of the soleus from its attachments to the tibia or fibula. By elevating that muscle the nerve will be found resting upon the deep muscles of the calf. At the internal malleolus the posterior tibial nerve may be the seat of traumatisms, accidental or operative. This nerve lies posterior to the artery at this point, and may be exposed by a curved incision an inch or two in length.

The **surgery of the sympathetic system** is limited to the cervical division; injuries to the great plexuses in other parts of the body, such as the celiac, are beyond surgical intervention. The **cervical sympathetic** may be injured by deep wounds of the neck and in deep operations upon the neck; it may be pressed upon by tumors or by deep cervical abscesses. Abbe[1] reports a case of fibrosarcoma of the cervical ganglia. He collected 43 cases of multiple neuromata in which the sympathetic system was more or less involved.

The *symptoms* of irritation of the cervical sympathetic are as follows: The eye-slit increases in width, the skin of the neck and face is pale and cold, the pupils are dilated, the eyes sunken; the sweat, the nasal secretion, and the saliva are diminished. Section or destruction of the nerve gives the exact reverse of these symptoms.

Surgery of the sympathetic at the present time has its widest field in operations upon the cervical ganglia for exophthalmic goiter and epilepsy. These operations find their most ardent supporters, however, among the French surgeons. Jonnesco recommends section of the cervical sympathetics in exophthalmic goiter, epilepsy, hysteria, chorea, tumors of the brain, and glaucoma.

[1] *Annals of Surgery*, 1898, vol. xxvii., p. 487.

The cervical ganglia may be reached through an incision at the posterior border of the sternocleidomastoid, beginning a short distance below the tip of the mastoid. The ganglia will be found posterior to the great vessels, between their sheath and the prevertebral group of muscles.

For exophthalmic goiter resection of the nerve or of one or both ganglia, on one or both sides, may be resorted to. For epilepsy, both the upper cervical ganglia, on both sides of the neck, including the cords connecting them, should be removed. The value of these operations has not yet, however, been fully demonstrated.

CHAPTER XXVII.

SURGERY OF THE HEART AND BLOOD-VESSELS.

HEART AND PERICARDIUM.

THE surgery of the heart and pericardium is in an undeveloped condition. There seems, however, to be no *a priori* reason why the heart and pericardium, especially the latter, in case of accident or disease, should not be amenable to surgical treatment, yet rarely has any attempt been made to treat wounds of the heart.

Here and there in the current literature of surgery may be found carefully reported cases of direct injury to the heart followed by recovery, and the deductions from these cases should lead surgeons to bolder methods of treatment in these hazardous cases. For example, in the index catalogue of the library of the Surgeon General's Office, U. S. A., there are reported 22 cases of direct injury to the heart, all of which lived over three hours; 17 lived over three days; 8 lived over ten days; 2 lived over twenty-five days; 1 died on the fifty-fifth day, and there are 3 well-authenticated recoveries.

The lesions of the heart and pericardium which may be treated surgically are the result of both injury and disease, and they comprise wounds and ruptures, effusions or hemorrhages—often resulting in distention of the pericardium and pressure on the heart. Rupture of the heart never occurs unless the heart-muscle has been previously weakened by disease. Traumatism or sudden obstruction of the coronary arteries may be the immediate cause of rupture of the heart when any predisposing condition exists. It is a calamity usually resulting in immediate death, and is accompanied by intensely severe precordial pain. In case the rupture is a small one, death may not be instantaneous, and life may be prolonged for several hours. In such a case a diagnosis might be made.

The following quoted cases are of interest in this connection: Hutchinson[1] reports a traumatic rupture of the heart due to the kick of a horse on the precordia. The patient lived four hours after the injury, and at the autopsy there was found no fracture of the ribs or sternum, but a rupture ¼ inch in length at the apex of the right ventricle. Groom[2] reports the case of a boy who had a contusion of the chest, who lived one month after the injury; and at the autopsy there was found a rupture of the wall of the left ventricle. No other circumstances of the case are given. The fatal result in cases of rupture of the heart is due either to shock, to an inability of the heart to contract owing to its injured muscle, or to pressure on the heart by hemorrhage distending the pericardium and preventing its expansion.

Wounds and injuries of the heart and pericardium occur in connection with injuries to the thorax. The most common are shot- and stab-wounds, while perforations and tears in the pericardium by the

[1] *Brit. Med. Jour.*, 1894, vol. ii., p. 1427. [2] *Lancet*, 1897, vol. i., p. 1202.

broken end of a rib or by a perforating foreign body have been reported. The possibility of a wound of the heart or pericardium should always be considered in perforating wounds of the chest in the cardiac region.

Rehn,[1] of Frankfort, in speaking of wounds of the ventricle as compared with wounds of the auricle, states that wounds of the auricle are much more fatal than those of the ventricle, owing to the thinness of the auricular wall.

The **symptoms** of wounds of the heart, when death is not immediate, are profound shock, severe pain, syncope, hemorrhage either externally or into the pleural or pericardial cavities, diminution of the heart-sounds, and possible enlargement of its percussion area.

The **treatment** should first be directed to the relief of the general symptoms. The foot of the bed should be raised, the patient surrounded by heaters, stimulants administered only in sufficient quantities to support the flagging heart, and morphin given in small amounts repeated frequently enough to ease the pain. The question of operation is then to be considered. No person should be allowed to die from a wound of the heart without an operation being attempted, when such an effort would give the slightest possible hope of a favorable outcome.

Under light anesthesia a flap should be reflected from the chest-wall over the wound, and a sufficient portion of one or more ribs resected to give access to the wounded heart. The pericardial wound should be enlarged if necessary, and fine silk sutures used to close the heart-wound. The pericardium should be irrigated out with hot sterile salt solution.

It is safer not to suture the pericardium completely, but to insert through the external wound into the pericardial cavity a small wick of gauze for drainage.

There have been several cases reported of recovery following attempts to suture or to control hemorrhage from the heart-wall.

Spencer[2] reports a case of a man twenty-eight years of age who was stabbed through the third left costal cartilage. The wound was packed with gauze, and the patient lived seventy-nine days. At the autopsy there was found a scar 5 mm. ($\frac{3}{16}$ in.) in length in the right ventricle, and a smaller scar on the inside of the heart, just below the pulmonary valve.

Ferranes[3] reports a case of a woman who was stabbed, where the fourth and fifth ribs at their costal junction were resected and a tampon was introduced into the pericardium to control the wound in the heart. Recovery occurred. The particulars are not sufficiently accurate to be of value.

Turner[4] reports a case of a child two years of age, where he cut down upon a wound in the heart, sutured it, and recovery occurred. No other facts are given.

Rehn[5] of Frankfort reports a case of knife-wound of the left chest through the fourth intercostal space, in which a portion of the fifth rib was excised, the pericardium opened, and a wound 1½ centimeters (0.6 inch) long was found in the right ventricle. The pericardium was packed with iodoform gauze. The patient had an attack of purulent pleuritis, but finally completely recovered.

Williams[6] reports a case of stab-wound where the fifth rib was temporarily resected; the wound in the pericardium was found to be 1¼ inches long and the wound of the heart $\frac{1}{10}$ inch long. The pericardium was irrigated with sterile salt solution, and the wound in the pericardium was closed with fine catgut sutures. The external wound was closed with sutures. The patient three years later was well.

[1] *Lancet*, 1897, vol. i., p. 1306. [2] *Brit. Med. Jour.*, 1896, vol. ii., p. 1129.
[3] *Gazette Medicale di Roma* (*Med. Record*, vol. li., p. 438).
[4] *Brit. Med. Jour.*, 1896, vol. ii., p. 1440. [5] *Lancet*, 1897, vol. i., p. 1306.
[6] *N. Y. Med. Record*, 1897, vol. li., pp. 437–439.

Occasionally cases are reported of wounds of the left ventricle where recovery ensued without suturing. For example:

Deane[1] reports a stab-wound of the left ventricle. Recovery. No suturing.

As illustrating a method of exposure of the heart and pericardium in stab-wounds of the cardiac region, Roberts's article on the subject of Suppurative Pericarditis, which was read before the American Surgical Association in 1897, is of interest. He proposed an operation consisting of a chondroplastic method of pericardotomy, by a trap-door excision of costal cartilages, which avoided injury to the pleura and mammary vessels.

An extremely suggestive case as to the possibilities of cardiac surgery is the one reported by F. C. Shattuck and C. B. Porter[2] of cure of a purulent pericarditis. The steps of the operation recommended by Porter are:

An incision is to be made from the middle of the sternum outward over the fifth costal cartilage to its junction with the rib. The soft parts are cleaned from the cartilage with a periosteum elevator, care being taken not to wound the pleura. The cartilage is divided with bone-forceps from the rib and the sternum. The internal mammary artery and vein are thus exposed, ligated in two places, and divided between. The triangularis sterni is separated from the sternum and pushed to the left.

A little careful dissection with the director, in case fat is encountered, exposes the pericardium, which is normally much thicker than the pleura. An aspirating needle should now be introduced, if this has not been previously done, in order to corroborate the diagnosis. If confirmed, the knife should follow the needle. The incision in the pericardium is best made obliquely downward and outward, beginning close to the excised border of the sternum. The edges of the pericardium should be stitched to the soft parts.

Irrigation should always be employed, with the object of removing any masses of fibrin which may lie at the bottom of the cavity, and if there are many such masses, it should be continued until the fluid returns clear. The fluid may be weak sublimate or carbolic solution or salt solution, according to the preference of the operator. The fluid must be warm and have free exit.

Drainage is best provided by two rubber tubes, one long and reaching to the bottom of the sac for the inflow, and a short tube just entering the sac for the outflow. As the discharge diminishes one tube may be removed, and finally gauze-drainage inserted.

One of the most interesting cases of spontaneous recovery from a gunshot-wound of the heart is reported by C. H. Mastin,[3] of Mobile, Ala. A man aged thirty-two was fired at from an ambush, and his left chest was perforated by a 38-caliber bullet. It entered the rear of the chest, just below and to the outer side of the angle of the scapula, at which point it entered the chest between the seventh and eighth ribs. It passed through the entire chest and emerged from the fourth intercostal space, 2½ inches from the midsternal line. Upon this anatomical location it is not possible for the heart to have escaped direct penetration. The patient fully recovered.

Eiselsberg[4] of Vienna reports a case where a purulent pericarditis developed after a stab-wound of the pericardium in a boy seventeen years of age. Puncture of the pericardium having been performed several times without relief, an incision was made, the cartilage of the fourth left rib was resected and the thickened pericardium exposed. This was opened by a transverse incision 4 centimeters (1⅓ inches) in length, and 2 liters (2.1 quarts) of a seropurulent fluid were evacuated. The cavity was irrigated out with warm salicylated water, the borders of the pericardial incision were stitched to those of the wound, two drainage-tubes inserted, and complete recovery took place in four weeks.

The cases of traumatism to the heart are few in number, and some of the most instructive cases are appended.

Dalton[5] of St. Louis reports a case of a man, aged twenty-two, who had a wound of the pericardium. He was seen an hour after the injury, and his immediate symptoms were very slight. Ten hours later his temperature rose to 101° F., pulse to 112, respirations to

[1] *Pacific Med. Jour.*, 1895, vol. xxxviii., pp. 209–211.
[2] *Boston Med. and Surg. Jour.* [3] *Trans. Am. Surg. Assoc.*, vol. xiii., p. 273.
[4] *Wiener klinische Wochenschrift*, Jan., 1895. [5] *Annals of Surgery*, Feb., 1895.

40. The entire left side had become dull. An incision 8 inches long was made over and parallel with the fourth rib, and 6 inches of the rib were excised. The pleural cavity was found filled with fluid and clotted blood. There was a wound in the pericardium 2 inches in length, which was sutured with much difficulty, owing to the rapidity of the heart's action (140 a minute). His recovery was rapid and uninterrupted.

Marks[1] of St. Louis reports 2 cases of stab-wound of the heart. Death occurred in the first case, the stab involving the right ventricle. The second case recovered after a stab that penetrated the left ninth intercostal space, the diaphragm, the pleura, the pericardium, and the apex of the heart. The entrance-wound was enlarged under an anesthetic, 1½ inches of the ninth and tenth ribs were excised, the wound being packed with iodoform gauze.

Lumniczer[2] reports 5 cases of wounds of the heart which are of a good deal of interest, and he concludes that the diagnosis of wounds of the heart may be made by means of local and general symptoms, of which the most important is compression of the heart. The signs consist of an increase of the area of cardiac dulness, splashing sounds synchronous with the heart-beats, weakness and irregularity of the pulse. It is obvious from the cases that he reports that surgical interference is demanded wherever the effused blood compresses the heart.

One of the most suggestive cases as to the wisdom of interference in suspected ruptures of the heart is that of Flamet,[3] who reports a case of a soldier who, while attempting to lift the trunk of a tree, was seized with a sudden severe pain in the right chest. It was thought that he had ruptured a costal cartilage by the action of the pectoralis major muscle. He was examined at the hospital the next day, but no lesion could be found, and the heart and respiration were normal. He walked about the yard and felt comfortable during the day. The following morning he suddenly complained of pain and expired almost at once. At the autopsy an ordinary sewing needle was found to have penetrated the chest-wall in the fourth right intercostal space and was buried in the pericardium. The pericardial cavity was found to be filled with blood, and this it is which is significant and should be recognized as a demand for surgical interference. On the surface of the right ventricle were found two small erosions, one of which disclosed an opening into the cavity of the heart.

Another case which shows the traumatism that a heart may receive and yet recover from is recorded by Cox,[4] who found a 32-caliber rifle-ball in the left ventricle of a bear which had been caught in a trap. The ball was encysted, and old pericardial adhesions were present.

In conclusion, it may be said that an exploratory operation is advisable in any case where a wound of the heart or pericardium is suspected, for the following reasons: 1. To secure asepsis; 2. To prevent the outpouring of blood from a possible wound in the heart-muscle into the pericardium, and by that means supradistending the pericardium and stopping the heart's action.

INJURIES OF THE BLOOD-VESSELS.

The surgery of the blood-vessels may be divided into two classes: 1. *Injuries*; 2. *Diseases*.

As the result of injury to a blood-vessel there occur several forms of hemorrhage. These are known as *arterial*, *venous*, and *capillary*.

Hemorrhage.—*a.* Arterial; *b.* Venous; *c.* Capillary.

In order to understand hemorrhage intelligently it will be necessary to recall the anatomy of the vessels.

All of the arteries have distinct coats; the internal or endothelial is known as the *tunica intima*, the middle muscular coat as the *tunica media*, and the external connective-tissue coat as the *tunica adventitia*. The two inner coats are intimately connected, but together may be easily separated from the outer one, which is dense and firm.

The *tunica intima* is a serous lining continuous throughout the vas-

[1] *St. Louis Med. Fortnightly*, Jan. 16, 1894.
[2] *Deutsche medizinal-Zeitung*, Berlin.
[3] *Archives de Médecine et de Pharmacie Militaires*, Paris, Nov., 1892.
[4] *Med. World*, Philadelphia.

cular system. It has no vessels and is composed chiefly of an epithelial lining and a layer of longitudinal elastic fibers and connective tissues.

The *tunica media* consists of two layers—an elastic and a muscular coat—whose fibers are arranged in a circular direction, and give to the artery its patency, form, and elasticity. The elastic fibers predominate largely in the aorta and its large branches, while the muscular fibers predominate in the smaller arteries.

The *tunica adventitia* is a tough membranous coat composed mainly of connective tissue. It gives to the arteries their chief strength and firmness, and from it the inner coats derive their nerve- and blood-supply.

Arterial Hemorrhage.—When the artery is divided, an intermittent stream of bright-red blood spurts from the proximal end of the injured vessel. However, in case of partial asphyxia from ether or other cause the blood is of a dark-red color like venous blood. The spurting stream which is usually seen is synchronous with the heart-beat, but if the hemorrhage comes from a deep wound this spurting is obscured. This is also the case where severe hemorrhage has occurred or where there is great cardiac weakness from lowering of the arterial pressure. Bleeding from large arteries must be controlled mechanically, while bleeding from the smaller arteries usually ceases on account of the retraction of the vessels within their sheaths and the spontaneous clotting of the blood.

Venous Hemorrhage.—When a vein is divided there is a continuous flow of dark-red blood, and, unlike arterial hemorrhage, the flow is greater from the distal end of the severed vessel than from the proximal end. Venous hemorrhage is not often dangerous, unless it occurs from a large vein near the trunk or from a large branch near a main vein. Fatal hemorrhage occasionally occurs from a ruptured varicose vein in the leg, owing to the valves in the vein becoming inefficient from dilatation of the vessel. In a hemorrhage from a vein the simple expedient of elevating the limb and applying slight pressure to the bleeding point quickly controls the hemorrhage. A serious danger in connection with venous hemorrhage from large trunks, especially in the neck, is the entrance of air into the circulation, forming air-emboli.

Capillary hemorrhage differs from arterial and venous hemorrhage in that blood flows from a large number of minute points in the tissues rather than from a single vessel of considerable size. The blood seems to well up from the wound like water from a spring. It is bright red in color, and unless from a constitutional dyscrasia always ceases spontaneously from the coagulating property of the blood.

Control of Hemorrhage.—The blood and the vessels have been provided with a number of important properties for the control of hemorrhage, which in the majority of cases are sufficient to prevent a fatal result. These are coagulation of the blood and the formation of thrombi; retraction and contraction of the vessel-walls; and the contraction and pressure of the surrounding tissues. After a serious loss of blood there is cardiac weakness and a consequent falling off in the blood-pressure, which lessens the loss of blood and favors coagulation. The underlying principle in the control of all kinds of surgical hemorrhage is the proper application of pressure. Constitutional treatment

by the administration of ergot, iron, opium, etc., to lower the blood-pressure and favor coagulation, lowering of the head to prevent fatal syncope, and the transfusion of a normal salt solution, are all valuable adjuvants.

There are a number of devices for controlling hemorrhage by pressure, many of which are always available. The most important of these are *digital pressure*, *improvised tourniquets*, or *pressure by a compress pad* and *bandage*. Other measures are packing a wound with gauze, the use of hemostatic forceps for temporary compression, torsion, and ligation. In addition to these, *position*, *heat*, *cold*, *styptics*, and the *actual cautery* are frequently of great value. The details for the treatment of hemorrhage and the applications of the various remedial measures will be found in the chapter on Minor Surgery.

Rarely in these days of antisepsis does a secondary hemorrhage take place. It may, however, be due to the slipping of a ligature, to an atheromatous artery, to sloughing in a wound that is the result of any septic process, or to gangrene. Arterial hemorrhage may be primary—recurrent within twenty-four hours—or secondary, from any time after this until the wound in the vessel is healed.

In pre-antiseptic days secondary hemorrhage was of frequent occurrence, and often took place when the ligature separated, which was from the twelfth to the sixteenth day. The treatment of secondary hemorrhage is as follows: In case the bleeding is confined to a small amount of oozing, packing the wound with iodoform gauze and the application of a firm bandage with compression are usually sufficient for its control. If, however, the hemorrhage becomes profuse, an Esmarch tourniquet must be applied, or digital pressure made over the artery, the wound opened, and a ligature applied to the ends of the bleeding vessel. In a sloughing wound or in a nearly healed stump it is often advisable to ligate the vessel in continuity.

Air-embolism, or the entrance of air into the circulation, aside from where it enters the uterine sinuses, occurs exclusively after injury to the veins, especially those at the base of the neck—*i. e.*, the jugular, the superior vena cava, the innominate, the subclavian, and the axillary. The facts that these are large veins with a stream of blood running downward toward the heart, that they usually do not collapse when wounded, being held open by their attachments to the surrounding connective tissue and fascia, and that when inspiration occurs the blood-pressure becomes negative in these veins, all favor the entrance of air when they are wounded. The air rushes in with a peculiar hissing or gurgling sound, and if in sufficient quantities death is almost instantaneous. Single small bubbles of air are not necessarily fatal, but may cause labored breathing and tumultuous cardiac action. Death is due to the air collecting in the right side of the heart and preventing the contraction of the right ventricle, which finally stops the heart in diastole.

Treatment of Air-embolism.—Unfortunately the accident is not usually recognized until the serious condition of the patient warns the surgeon of approaching death. It more commonly occurs in a surgical operation than in the case of an accidental or a self-inflicted wound. When a large vein is cut it should be instantly compressed on the

cardiac side by the finger, and the wound should be kept filled with sterilized water until the vessel is ligated. As soon as the bleeding vein is secured, the patient's general condition should receive attention. Inhalations of oxygen, forcible expiratory movements by compression of the chest, electricity to the chest over the heart, bandaging of the limbs, and subcutaneous injections of strychnin or atropin should all be tried. Operations in the vicinity of the veins in the lower part of the neck should be conducted with the greatest care, and an assistant should stand near at hand, ready to apply compression in case of need.

Wounds of the arteries and veins occur in connection with wounds of all kinds and in every part of the body, and give rise to the different varieties of hemorrhage previously enumerated. The first indication in these wounds is to control the hemorrhage by compression, ligature, or packing.

It is very rare that in an operation a surgeon will be called upon to suture an artery, but it has been demonstrated by Gluck[1] and also by Heidenhain that the axillary artery, if it is not completely divided, may be restored in its continuity. The edges of the artery are seized by forceps, fine catgut sutures are introduced through the adventitia, and the wound is packed down to the sutured vessel. Heidenhain examined his case of suture of an artery six months later and found no evidence of a traumatic aneurysm.

Not infrequently in operations where large veins are involved a surgeon will find a bleeding point on the wall of a vein which requires repair. This can be done by seizing the bleeding point and applying a ligature to pucker up the wall of the vein, and, as has been done in treating arteriovenous aneurysms, the wall of the vein might be sewed in on itself by fine catgut sutures in the axis of the vessel.

Rupture of an artery occasionally occurs as the result of direct or indirect violence. The rupture may be complete through all three coats, or it may be only partial through one or more coats of the vessel. The walls of an artery may be torn as the result of a blow, or the wall may give way from increased blood-pressure when weakened by atheroma. If an artery is stretched from overextension, especially at the knee-joint, or where the vessel is caught against the bone or between the fragments of a fracture, or where it is bruised in the reduction of dislocations at the hip- or the knee-joint, a rupture may take place. Partial rupture of an artery resulting in aneurysm may come on without apparent violence, as a sequel to endarteritis. When rupture occurs in a large artery with no external wound, the blood spreads through the tissues, forming an *arterial hematoma*, and the bleeding internally is controlled only by the pressure of the surrounding tissues. A large ill-defined swelling forms, giving rise to great pain, and, if it continues, the limb becomes cold, swollen, numb, and pulseless. There is usually no pulsation in the swelling. The diagnosis in these cases rests frequently between a ruptured vessel and a deep abscess and is often very obscure, and aspiration may be necessary in case of doubt. If rupture of a large blood-vessel takes place into one of the large cavities of the body, fatal hemorrhage is almost inevitable.

[1] *Centralbl. für Chirurgie*, 1895, No. 49.

The *treatment* in these cases varies according to the character of the injury, the magnitude of the hemorrhage, its location, and the age and condition of the vessels of the patient. If the injury is of such a character that it is believed that a large vessel has been torn across, an incision should be made, the blood evacuated, and the torn vessel ligated. This is equally true if the hemorrhage into the surrounding parts is increasing. If, however, the patient's vessels are seriously diseased by endarteritis or atheroma, it may be difficult to find a place to secure the artery. General atheroma is a contra-indication to any operation in these cases. Ordinarily the limb should be carefully supported on a pillow, wrapped in sheet-wadding and kept warm, and watched. If the swelling increases there is danger of gangrene, and an operation may be advisable. Rupture of diseased arteries from aneurysm results in nothing different from simple traumatic rupture unless it occurs into one of the large cavities of the body, in which case there is usually a fatal hemorrhage.

A **traumatic aneurysm** differs from an arterial hematoma in the fact that all the coats of the vessel are not ruptured. The remaining uninjured coats being insufficient to withstand the blood-pressure, the vessel gradually stretches and gives way at the weakened point, and an aneurysmal sac is formed. The symptoms, treatment, and progress of a traumatic aneurysm are identical with those of an ordinary aneurysm. A traumatic aneurysm may be distinguished from an arterial hematoma by its distinct outlines, by its pulsating character, and by the presence of the normal pulse in the limb.

Rupture of a vein often occurs as the result of traumatism to a varicose vein. When the rupture is subcutaneous a *venous* hematoma forms, often of considerable size and just beneath the skin. Usually, however, the hemorrhage ceases, owing to the low blood-pressure in the veins, before the amount of extravasation becomes dangerous. The extravasated blood is generally absorbed. Not infrequently, however, owing to the low state of the vitality of the patient and the tension on the skin, the extravasation is followed by inflammation and suppuration. Where this occurs there is increased pain, with redness and swelling. In such cases, where it is clearly determined that inflammation has taken place, an early incision should be made, the blood-clot turned out, and the wound packed with iodoform gauze. Open ruptures of the vein should be controlled by elevating the limb and applying pad-pressure to the point of rupture, under antiseptic precautions.

Repair of Arteries and Veins.—When an artery is divided subcutaneously there is always a considerable hemorrhage, with a collection of blood-clot outside and inside the ruptured vessel. If there is no open wound, the clot gradually becomes absorbed and granulation-tissue takes its place. Where the divided vessel is large and the wound involves only a part of its wall, the granulation-tissue eventually becomes connective tissue and forms a cicatrix. This cicatrix is seldom sufficiently firm to withstand the blood-pressure, and an aneurysm is likely to form at the injured point. When the artery is completely ruptured or when the vessel is firmly ligated, the blood in the injured ends coagulates, forming what is known as a thrombus (see Fig. 38,

page 136). This thrombus extends from the point of interruption in the vessel in both directions—proximally to the nearest branch given off, and distally but a short distance. This thrombus-formation takes place in any vessel whenever the normal integrity of its epithelial lining is in any way impaired. After the thrombus is formed, it undergoes a change which consists of the gradual supplanting of the thrombus by cellular infiltration, by the formation of granulation-tissue and of blood-vessels which penetrate the thrombus in all directions. This finally becomes connective tissue and completely replaces the thrombus. In this way is formed the cicatrix which successfully closes the vessel (Fig. 437). The replacement of the thrombus by connective

FIG. 437.—Femoral artery of man three months after ligature; proximal end, termination of healing process. The cicatrix, composed partly of muscular cells, is penetrated by a small vessel. Below is the fibrous tissue which unites the proximal to the distal end (Warren).

tissue is largely accomplished by a proliferation of the endothelial cells of the intima, and the time required for the completion of the process in the vessel varies greatly with the size of the vessel and with the power of repair possessed by the individual. The same process of repair occurs in the veins as in the arteries, but in the veins thrombi form more easily and are more extensive than in arteries.

DISEASES AND INFLAMMATORY CHANGES OF THE BLOOD-VESSELS.

Arteritis is a distinct form of inflammation which involves all three coats of the wall of an artery.

Acute arteritis may occur as a primary affection, as the result of an injury or of direct bacterial infection; it may be secondary to a septic thrombosis or embolism forming or lodging in an artery, or to the existence of inflammatory disease in the surrounding tissues. There are many constitutional diseases and conditions—for example, rheumatism, gout, syphilis, and alcoholism—which favor the formation of chronic arteritis.

The results of **chronic arteritis** in the vessels themselves are fatty degeneration, calcification, gummata (occasionally resulting in ulceration), suppuration, occlusion, dilatation, aneurysm, and rupture of the vessel-wall. Arteritis, if secondary to disease in the surrounding tissues, first appears in the adventitia, in which case it is termed a *periarteritis.* If the inflammation first rises in the intima, as from traumatism, in the ligation of a vessel in an infective process, it is known as an *endarteritis.* Where the inflammatory process arises in or is confined to the middle coat of the vessel, it is termed a *mesarteritis.*

Traumatic Arteritis.—This is the most simple form of inflammation, and arises from the ligation of a vessel, or after wounds or bruises, or following the lodgement of non-infective emboli. The small contiguous vessels dilate, lymph is poured out into the adjacent tissues, and granulation- and connective tissue form, resulting in a cicatrix in the wall of the vessel.

Suppurative arteritis commonly begins in the intima from the presence of an infected embolus, or it may occur as a peri-arteritis, in which case organisms must be brought to the vessel by lymphatics or must have entered through a wound. Septic emboli lodging in a vessel produce a very acute arteritis, with rapid ulceration and destruction of the vessel-wall. This occurs during the course of an ulcerative endocarditis. When the suppurative arteritis begins in the adventitia the course of the process is much slower, and the vessel often gradually ulcerates through or becomes weakened and gives way. This is probably partly due to the fact that the outer coat of the artery is more resistant than many tissues, and partly because septic emboli contain more virulent organisms. Hemorrhage of an alarming nature rarely takes place as an immediate result of this process, but death results from the constitutional infection which gives rise to the septic emboli.

Atheroma.—The most frequent result of arteritis is atheroma; it is a very common condition in late adult life, but rarely gives rise to symptoms. It often exists for a long time before it becomes evident, and probably begins between thirty and forty years of age, especially in those addicted to the abuse of alcohol. The places in which we find atheroma are those portions of the large vessels which are subjected to the greatest strain; as, for example, the arch of the aorta, the convex portions of the curve in vessels, the points of division of arteries, and at the origin of branches. Atheromatous arteries occur more commonly in plethoric persons of a gouty or rheumatic diathesis,

in those with nephritic or cardiac disease, and in alcoholic and venereal patients. The disease may occupy successive segments of the vessel or it may occur in large or small patches, variously scattered about. It is first seen in the intima of the vessel as yellowish-gray shining spots, slightly raised above the surface. The spots increase in size, often coalesce, and then become more yellow and distinctly elevated. This yellow exudate, which occurs beneath the lining of the intima, is gradually replaced by a deposit of lime salts. Then the muscle-fibers begin to waste, and the vessel loses its elasticity and becomes rigid. Atheromatous arteries are stiff and inelastic, and the parts they supply are cold, congested, and badly nourished. If the salts are deposited in successive rings around the artery, it is known as annular calcification; if in patches, it is called laminar calcification. The vessels most commonly attacked by atheroma are the aorta, the iliac, femoral, coronary, and radial arteries. The presence of atheromatous blood-vessels should not be overlooked in deciding as to the advisability of an operation, for it is well known that the loss of elasticity in the blood-vessel may produce thrombosis, embolism, aneurysm, or apoplexy.

Arteritis deformans is the name given to a condition which is the result of atheroma, in which extensive dilatation and pouching of the walls occur. In the dilated portions the media has undergone extensive fatty degeneration, while the calcareous matter is found to be most abundant in those parts of the vessel-wall which are the least dilated.

Endarteritis obliterans is one of the evil results of chronic arteritis, and consists of the permanent occlusion of the lumen of the vessel. The process begins with a cellular infiltration of the intima, which subsequently becomes changed into connective tissue. The media may also become involved (Fig. 438). Infiltrations of the walls of the vessel

FIG. 438.—Tibial artery from a case of senile gangrene of the foot (obliterative endarteritis) (Warren).

occur in syphilitic and tubercular inflammation. Gangrene of the part may occur from endarteritis obliterans.

Syphilitic arteritis is a special form of the disease, especially dangerous in that its most serious lesions are found in the vessels of the

brain. The arteries of small caliber and the aorta are most frequently involved. The process consists of cell-infiltration into the intima, and the lumen of the vessel may be partially or completely occluded, resulting in endarteritis obliterans.

Rheumatic arteritis occurs associated with acute rheumatism, and while not as common as rheumatic endocarditis, yet it occasionally occurs in the aorta.

Symptoms of Arteritis.—Arteritis may be recognized by pain and tenderness along the line of the blood-vessels. The vessel, if superficial, may be felt as a cord, and is frequently almost pulseless. The pulsation may be modified so that it is shortened and jerky, according to the amount of obstruction. When the vessel becomes occluded there is often great pain with a feeling of great tension, a loss of power in the part; and, while gangrene may result if the vessel is an important one, yet collateral circulation may be established.

Treatment.—The *acute* forms of arteritis are treated by the administration of opium, with rest, elevation of the limb, and cold applications to the part. If there is an active inflammation around the artery—a peri-arteritis—poultices may be applied, and under certain circumstances an early operation for the evacuation of septic or purulent material may be called for. In *chronic* arteritis the existence of any predisposing disease, such as rheumatism, gout, syphilis, or nephritis, should be recognized in order to receive appropriate treatment. The local treatment should consist of rest, elevation of the part, and careful bandaging applied to the limb in such a manner as will assist the circulation. The skin and kidneys should be kept active by daily warm baths and diuretics. The diet should be plain and moderate in quantity, and the bowels kept free. In all cases of this description there is danger of aneurysm-formation and apoplexy, and the tension in the arteries must be reduced to a minimum by the avoidance of all excitement or violent exercise. In senile cases the danger of gangrene should be avoided as far as possible by keeping the extremities warm and protecting them from injury.

Anatomy of the Veins.—The veins, like the arteries, have three distinct coats: The *intima* corresponds to and is a continuation of the lining of the arteries; the *media* is made up of longitudinal and elastic fibers; and the *adventitia* consists largely of areolar tissue. The thinness of the walls of the veins as compared with those of the arteries is the main difference between them, and this is especially so in the muscular coat. For this reason the veins lack firmness and contractility, and the absence of elasticity is the reason they do not gape open when divided. The thinness of the walls of the veins renders them peculiarly liable to distention and stretching, and to compensate for this lack of elasticity and to assist in supporting the column of blood they are provided with valves, which are especially useful in the lower extremities.

Phlebitis.—An inflammation of all the structures which go to make up the wall of a vein is termed phlebitis. A similar nomenclature to that used for arteries is used for inflammations of the various coats of a vein. For example, *endophlebitis*, *mesophlebitis*, and *periphlebitis* represent inflammatory processes as situated in the internal,

middle, and external coats. Clinically, however, phlebitis and periphlebitis are the only forms of the disease which can be recognized, and even that distinction is not always possible. Phlebitis may be acute, subacute, or chronic, and it occurs more frequently than arteritis. It is usually confined to a single vein in contradistinction to inflammation of the arteries, where usually a large number of vessels are involved. The vein may be inflamed throughout its whole length or only for a short distance. Acute phlebitis may be simple, plastic, or purulent. Simple acute phlebitis may be due to a number of constitutional diseases, such as rheumatism, gout, or syphilis, or it may occur in some infectious process, as, for example, typhoid fever or the puerperal state. It may also be due to traumatism, as in ligation; it often arises from a thrombus, an embolus, or the extension of an external inflammatory process.

Suppurative phlebitis usually occurs in the perivascular tissue, and is due to a simple phlebitis having become infected. It is seen in the sinuses of the mastoid, and occasionally occurs in cellulitis and in phlegmonous erysipelas.

Subacute and **chronic phlebitis** are often associated with varicose veins, or they may occur in the course of some constitutional dyscrasia, such as syphilis. This form of the disease usually attacks the outer coat of the vein, and is termed a periphlebitis. There is thickening of the walls of the vessel from the deposit of fibrinous material. It is naturally much less dangerous than an acute phlebitis. In phlebitis the coats become edematous and infiltrated with a serous exudate and with cells, and the walls become thickened and more vascular. When an inflammatory process begins to attack the intima and affects the endothelial lining, the formation of a thrombus begins. On the other hand, the thrombus may be primary and give rise to the foregoing process. The effect is the same in either case. If the inflammation subsides without suppuration, the exudate becomes partially absorbed and partially converted into fibrous tissue, but leaves a permanent thickening of the vessel-wall. The thrombus, which may or may not completely occlude the vessel, may be absorbed or organized. Subsequently the lumen of the vein tends to regain its normal size and appearance as the clot becomes absorbed or organized. Primary thrombi are apt to develop in the veins, in the vicinity of the valves, on account of the sluggish current at these points, and naturally at this point the lodgement of micro-organisms may take place. In suppurative phlebitis, if the lumen of the vein is completely occluded, disintegrated products of the inflammation are prevented from being swept into the circulation. If, on the other hand, the vein is not occluded or the thrombus itself undergoes degeneration, suppurating masses containing micro-organisms are carried by the circulation to various parts of the body and result in metastatic abscesses.

Symptoms.—The symptoms of phlebitis differ more or less with the cause of the disease. In the acute form the constitutional disturbance is marked. There are apt to be chills, high temperature, rapid pulse, severe pain, a dry, coated tongue, restlessness, and delirium. There are usually severe pain and tenderness along the course of the affected vein. The more superficial veins may be felt as small, hard,

knotted cords. The veins are distended, giving rise to mottling of the skin. If thrombi exist in the veins, especially in the deep ones, there is usually sufficient disturbance in the circulation to produce edema of the involved part. When the femoral or iliac veins are involved the disease is known as *phlegmasia alba dolens* ("milk-leg"). In the suppurative forms of the disease, if the infection is general, there are usually associated symptoms of septicemia. In the subacute and chronic forms of phlebitis the pain and tenderness are less marked and more circumscribed. Pulse and temperature are lower, delirium and chills are absent. The chronic form of the disease often accompanies varicose veins of the leg, which usually remain quiet if properly supported; but owing to the defective circulation in the limb, a subacute process is easily lighted up by a strain, a blow, or any unusual amount of exercise. Phlebitis may be mistaken for lymphangitis, neuritis, neuralgia, or rheumatism. In lymphangitis the skin is a brighter color, and there are often narrow reddened streaks running up the limb as the result of the infection. In neuritis and neuralgia the pain is apt to occur in paroxysms, but is not associated with superficial redness nor with heat. There is also less tenderness in neuritis and neuralgia than in phlebitis. Rheumatism, however, may often be differentiated only by treatment. In phlebitis the pain is usually increased by motion, and when the limb is allowed to hang down, the pain and throbbing are greatly increased. Gouty, rheumatic, or syphilitic phlebitis can be distinguished only by the history of the case.

Treatment of phlebitis consists in putting the patient to bed and giving absolute rest to the involved part. This is imperative in order that the danger from thrombosis may be minimized. If the thrombus should separate and cause an embolus, it may end in immediate death. The limb should be elevated, as this position favors the venous circulation, relieves the tension in the part, and prevents pain and throbbing. A large flaxseed-meal poultice should envelop the whole limb, and should be changed every two hours, if necessary. It gives the most satisfactory relief to the pain of an acute inflammation. Hot fomentations, evaporating lotions, lead-and-opium wash, opium and belladonna, and solutions of nitrate of silver are all recommended for external application, and are useful in the management of chronic cases. In acute cases the patient's physical condition may be seriously involved. In order to sustain the system forced feeding, if necessary, together with the administration of stimulants, should be used. Quinin, iron, and saline cathartics are all indicated. Naturally, if the condition is due to syphilis, specific treatment should be tried, and it is often necessary to administer potassium iodid freely and for a long time before any improvement occurs. The same is true of the gouty or rheumatic type of the disease, for which appropriate treatment must also be given. The type of the disease that occurs in stout, plethoric men who are hearty livers is peculiarly difficult to control. They should be restricted to a light diet, all stimulants prohibited, and the emunctories kept free. Massage should be entirely avoided, as there is danger of an embolus separating from a thrombus. Even when skilfully employed, it has been known to stir up a chronic phlebitis to an acute form. The patient should be kept in bed for many weeks after

all pain and tenderness have disappeared. At first, gentle passive motions are to be allowed, and then the patient may be up on crutches. At this time the limbs should be carefully bandaged with a flannel bandage, with moderately firm pressure. In the convalescent stage electricity may be used in restoring the strength to the atrophied muscles, and its use may be combined with controlled massage. In case of suppurative phlebitis with marked localized swelling and redness, where there is thought to be danger of abscess-formation, early incisions under antiseptic precautions are very important. By this means, if the thrombus which exists in the vein is not already invaded, or even if it is involved, septic emboli and pyemia may be prevented. Brilliant results are obtained in suppurative otitis media, with thrombosis of the lateral sinus, by early trephining of the mastoid. Occasionally cases of suppurative phlebitis have been successfully treated by excising the involved vein, and there can be but little doubt that it is a justifiable operation to ligate the cardiac end of a vein filled with a septic thrombus.

Thrombosis is the process of coagulation of the blood, during life, in the interior of the heart or a blood-vessel. The clot which forms is a thrombus, and is due to some interruption in the blood-current at a definite point. This is frequently due to a thickening of the endothelial lining of the vessel at the point where the thrombus is formed. A ligature, phlebitis, or varicose veins are the most common causes of thrombi. Acute rheumatism, syphilis, continued infectious fevers, or surgical shock where the heart is extremely weak, all favor the formation of thrombi. The local injury which occurs in the endothelial lining of the vessel may be due to a simple blow or pressure, to the presence of foreign bodies, or to any of the inflammatory diseases. Thrombi which are found during life are distinguished from clots which form in the vessel after death by their greater consistency and greater adherence to the vessel-wall. The adherence of the thrombus may be due to simple fibrin, or there may be definite tissue-formation between the thrombus and the vessel-wall. Thrombi may or may not occupy the whole lumen of the vessel. They are usually whitish in color, are cone-shaped, and project like a polypus in the direction of the blood-current. Thrombi are designated as *venous* and *arterial*, according to their location. Arterial is less common than venous thrombosis. Thrombi are also designated as red, white, and mixed thrombi, according to their color and composition, and as infective or non-infective, according to their pathogenic character. The infective and non-infective thrombi form in precisely the same way, but the infective thrombi contain bacteria which produce a purulent softening of the thrombus, so that it becomes a soft, friable mass, which may break up and enter the circulation in the form of septic emboli. A non-infective thrombus undergoes several changes after its formation, and in the course of time it becomes firm and hard. In its interior, especially in the larger thrombi, there may occur a non-septic softening caused by the breaking down of the cells. Occasionally a thrombus may undergo a complete absorption and entirely disappear, or it may become organized into connective tissue. This is known as organization of the thrombus, and it is due to gradual cellular infiltration and

the growth of connective tissue from the wall of the vessel. A thrombus may become calcified by the deposition of lime salts, and it is then known as a *phlebolith*.

The **symptoms** of thrombosis may be relatively slight until the thrombus reaches sufficient size to interfere with the blood-current. Then there suddenly occurs severe pain in the part, which is greatly increased upon motion or when the part is in a dependent position. Acute tenderness or induration occurs along the vessel; edema of the extremities with local redness and swelling is a part of the process. There is found considerable constitutional disturbance, with high temperature and a rapid pulse. Thrombi more frequently occur in the vessels of the extremities.

The **treatment** of thrombosis is of necessity expectant. Absolute quiet, in order to promote absorption of the clot and to prevent detachment of the thrombus, is imperative. Rest should be insisted upon until all acute symptoms have subsided, when the thrombus will either have been absorbed or have become attached to the vessel-wall, and the danger of embolism will have been reduced to a minimum. The limb should be elevated to relieve congestion and to favor the return of circulation. Large flaxseed poultices should be kept applied to the limb, or the limb may be carefully bandaged outside of a thick layer of cotton wadding. The employment of massage, blisters, iodin, and all counterirritant measures is to be carefully avoided in the acute stages of the process.

Embolism.—An embolus may be derived from a number of different sources—for example, from a disorganized thrombus, from calcareous and caseous deposition in the cardiac valves, from malignant growths, all of which may become detached and swept into the circulation. Occasionally, fat or air may accidentally be introduced into the circulation and act as an embolus. The place where the embolus lodges depends upon its size and its point of origin: those which come from the left side of the heart lodge in the arterial system, while those which separate from a thrombosis of a vein are carried to the pulmonary arteries. They are lodged at a point where the size of the blood-vessel does not permit them to advance further—generally where the large branches are given off, as there the vessels are apt to be diminished in size considerably. If the embolism obstructs and occludes one of the large branches of the pulmonary artery or the middle cerebral artery, instant death usually takes place. Emboli may undergo the same changes as thrombi—that is to say, they may be absorbed, organized, or softened. An occluding embolus in a healthy and well-nourished individual may occasion only temporary and local disturbance, as the collateral circulation may furnish a sufficient blood-supply to the part. Sudden occlusion of a large and important vessel, such as the femoral artery, will produce intense congestion, edema, gangrene, and frequently death. If the embolus is an infected one, the organisms which it contains set up a purulent necrotic process in the wall of the vessel, and this is known as a secondary abscess.

The **symptoms** of embolism are sudden in onset, and there are sharp pain and tenderness along the course of the vessel and the parts supplied by it. There are coldness, numbness, and pallor in the parts.

The symptoms of embolism are similar to those of thrombosis, except that they are more sudden and pronounced and much more serious.

The **treatment** of embolism, if the part involved is a limb, consists in rest, elevation of the limb, and the application of warmth to the part to favor the return of the circulation. Opium should be used to relieve pain, and a nutritious diet and a judicious stimulation are indicated. If gangrene occurs, as soon as a line of demarcation is established, the limb should be amputated. In the meantime antiseptic poultices should be applied and the patient's strength supported.

Varices or **varicose veins** in the extremities are at first nothing but simple distended veins, which later, as the result of their distention, become elongated, tortuous, and thickened. The same pathological condition exists in varicocele and in hemorrhoids, but these will be considered under their separate headings in another chapter. Varicose veins in the extremities are the result of a negative blood-pressure in the veins, brought about either by direct pressure on the vessels themselves or by the simple weight of the column of blood, which, not being forced along, overcomes the natural elasticity of the vessel-wall until it becomes dilated and then stretched. This frequently occurs in persons who stand a great deal. The blood is forced through the veins into the limbs largely by the alternate contraction and expansion of the muscles pressing on the veins, so that it causes a venous stasis in the legs. Other exciting causes are abdominal and pelvic tumors, effusions into the peritoneal cavity, gravid uterus, tight lacing, garters around the legs, and a weak heart. The disease occurs most frequently in women and in persons who have reached middle life. The varices begin by the gradual dilatation of the vein opposite the valves, where the weight of the column of blood is supported. This taking place alternately on opposite sides of the vein causes it to lengthen, and a tortuous vessel results. The knotting of the vein is the result of the pouching out of the vessel opposite the valves. Associated with the lengthening and pouching of the vein are inflammatory changes in the wall of the vessel. As a result of this the walls become thickened by the exudation of inflammatory products and the proliferation of connective-tissue cells. In this manner the localized attacks of phlebitis and periphlebitis which occur in connection with varicose veins may be accounted for. Varicose veins are usually easy to recognize, for they are found chiefly in the superficial vessels (Fig. 439). They are seen

FIG. 439.—Varicose veins.

as large, prominent, and tubulous veins, commonly on the anterior aspect of the leg, and unless they are actively inflamed are soft, easily compressed, and not painful. When the trouble has existed for a long time, owing to the excessive thinness of the vessel-wall the vessel may suddenly rupture and give rise to a serious and sometimes fatal hemorrhage. A varix of the internal saphenous vein protruding through the saphenous opening may easily be mistaken for femoral hernia, as it appears and disappears in getting up or lying down. It is diagnosticated from a hernia in that pressure over the ring does not prevent the varix from reappearing, while pressure easily controls a femoral hernia.

The **treatment of varicose veins** is palliative and operative. The former frequently gives relief when the disease is seen in its early stages. Any preventable cause, such as tight clothing, garters, etc., must be removed. The condition of the circulation and of the bowels must receive attention by giving suitable cathartics. A recumbent position with the limb elevated, and gentle massage in an upward direction, with the prohibition of sitting and standing, all favor the venous circulation, and with attention to the general health, administration of tonics, and later on suitable outdoor exercise, assist in restoring the normal tone of the vessel-walls. Absolute rest in bed for a few weeks is very desirable; but when this cannot be secured and the patient is allowed to be up, local treatment should be used. This consists of firm and well-applied pressure distributed evenly over the leg from the base of the toes to above the knee. The pressure must be applied in the morning, before the patient leaves the bed, while the limbs are elevated, and is to be removed at night only after the patient is in bed. A simple bandage made from a good quality of thin, firm "domets" flannel, 3½ inches wide, cut on the bias, is inexpensive and easily made, and may be efficiently applied with a slight amount of experience. A better support is a silk elastic stocking made to measure and fitted accurately to the limb. Rubber bandages are also used to a considerable extent.

The *operative treatment* of varicose veins aims at the obliteration of the lumen of the vein or the complete removal of the vessel. The application of caustics to the vein and the injection of carbolic acid are dangerous and practically obsolete methods. Acupressure and subcutaneous ligature to a vein, followed by compression, are rarely used. The most satisfactory method is excision of portions of the vein at various points in its course, although occasionally the greater part of the tortuous vein may be excised. After removal of the vein the wound is closed and primary union may be obtained. These operations should be performed under the strictest aseptic conditions, as the tissues involved possess extremely poor resisting qualities, and septic phlebitis and thrombosis are easily started up. It is scarcely necessary to say that an operation of this description is required only in those cases which palliative treatment cannot relieve.

An **arterial varix** or **cirsoid aneurysm** is a dilatation and elongation of the arteries similar to the varices which occur in the veins. When the large vessels are dilated and tortuous it is known as a cirsoid aneurysm. It may be congenital, but is usually acquired from unknown causes. It probably results from some inherent stricture or

defect in the arterial wall. It occurs chiefly in the arteries of the scalp, face, neck, palms of the hands, and soles of the feet. The diagnosis is easily established, as the tumor pulsates synchronously with the heart, and the peculiar tortuous convoluted condition of the mass is characteristic. A murmur is often heard over the tumor. If the tumor is increasing in size or if inflammatory changes due to pressure are likely to occur, with absorption of bone, ulceration, and hemorrhage, the tumor should be excised. Many forms of treatment have been tried—for example, injections of perchlorid of iron, direct pressure, application of ligatures to the main vessels, galvanopuncture, electrolysis, and subcutaneous ligation. Excision, however, of the whole mass is the most satisfactory method. The operation is often serious, owing to the large size of the mass and the quantity of blood that may be lost. If the tumor is not large nor increasing in size and does not cause pain or annoyance, an operation is not called for.

Angiomata are tumors composed for the most part of blood-vessels, but they differ from arterial varices in that the capillaries are dilated and the skin is involved. The larger forms are known as *cavernous angiomata* (Fig. 440), from the fact that the vessels are not only dilated

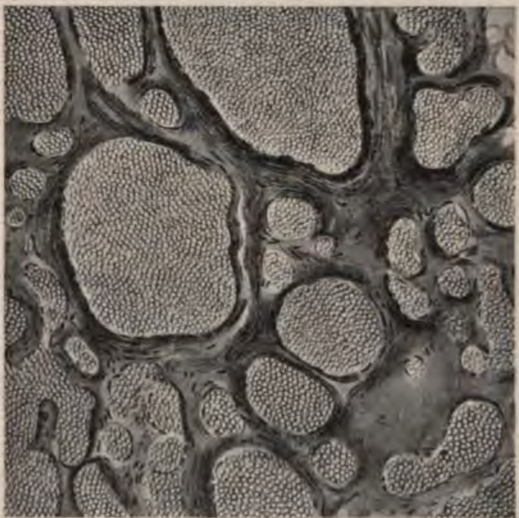

FIG. 440.—Cavernous angioma (Warren).

but also obliterated, and the blood is contained in open spaces. These tumors are usually congenital, and their cause is not known. They are found in the liver, kidney, spleen, and brain, and in bone, in the orbit, in the larynx, and occasionally in the breast (Fig. 441). The recognition of angiomata, unless they are deep-seated, is usually not difficult. The arteries leading to them are tortuous and dilated and visibly pulsate. There is often a distinct murmur, and by applying intermittent pressure alternate emptying and refilling of the tumor occur. Treatment by electrolysis, if the growth is small, may be successful and attended by little disfigurement. If, however, the growth is of considerable size, it should

be carefully dissected out, as in the case of any tumor, ligating such vessels as are necessary, and suturing the skin to secure primary union.

A **nevus** is a congenital disease of the capillaries or of the veins,

FIG. 441.—Angioma of the lip and the neck (Warren).

and is frequently situated upon the face. When the nevus involves only the capillaries of the skin, it appears as a slightly elevated area,

FIGS. 442, 443.—Nevus of the face.

varying in size from the head of a pin up to and involving the whole of one side of the face, and in color varies from a bright red to a dark purple (Figs. 442, 443). Nevi which cover considerable areas are

usually only slightly elevated above the skin, and are often purely cutaneous. They do not require operative interference unless there is an increase in their size after careful continued examinations extending over a length of time. The small cutaneous nevi may be lightly touched with the flat surface of an actual cautery, thus destroying the vessels with but little pain and leaving only a slight white scar. The nevi of larger size should be treated by actually perforating them with the cautery, by using electrolysis, or by the operation of complete excision. Nevi are never injected at the present time, owing to the danger of thrombosis and embolism (Fig. 444). Nevi which are

FIG. 444.—Nevus of the hand and the forearm. Case of L. M. Tiffany.

markedly pigmented are often spoken of as "moles." They may be of considerable size. They are not very vascular, and rarely show a tendency to spread or to ulcerate. These moles are the favorite seat of the development of the melanotic forms of cancer.

Aneurysm.—An aneurysm is a hollow tumor filled with blood, whose cavity communicates with the lumen of an artery, into which the blood-current flows to and fro. The walls of an aneurysm may or may not be composed of the coats of the artery, and hence aneurysms are divided into *true* and *false*.

A *true aneurysm* is one in which the walls of the aneurysmal sac are formed by the coats of the artery, at least one of which must be

FIG. 445.—Sacculated aneurysm (Keen and White).

intact. A *false aneurysm* is one in which there is no arterial coat, but the blood is contained in a sac of fibrous or other tissue.

There are many forms of aneurysm not of any practical importance, but which are recognized by different writers.

A *diffuse aneurysm* is one which, as its name implies, extends over a considerable area of space in the tissues. A *traumatic aneurysm* is one produced by direct trauma to an artery. The majority of diffuse or traumatic aneurysms are false aneurysms, and the blood poured out from the artery is simply confined by the surrounding tissues. A *dissecting aneurysm* is one in which there is a partial rupture of the wall of the artery, and in consequence there is a passage of blood between its coats. A *sacculated aneurysm* (Fig. 445) is a localized pouch bulging from one side of an artery. A *fusiform* or *tubular aneurysm* (Fig. 446) is a uniform spindle-shaped dilatation involving all the coats of the artery. A *hernial aneurysm* is one in which one of the coats of the vessel becomes protruded through an outer ruptured coat. An *arterio-venous aneurysm* is a condition in which an abnormal direct communication becomes established between the lumen of an artery and that of a neighboring vein.

FIG. 446.—Tubulated or fusiform aneurysm (Keen and White).

Aneurysm is essentially a disease of middle life, and occurs between the ages of thirty to sixty years. The most frequent seat of the disease is the thoracic aorta, and after that it occurs most frequently in the popliteal, the femoral, the abdominal aorta, the carotid, the subclavian, the axillary, and the innominate artery. All of these aneurysms present certain clinical symptoms in common, and the most characteristic is the development of an elastic, fluctuating, and pulsating tumor in the course of the artery, which may be diminished in size by exerting uniform pressure on its surface. On auscultation an aneurysmal bruit or murmur is heard over the tumor. Other common symptoms are those of pressure and weight, with dull, heavy pains, diminution of the volume of the pulse-beat in the vessel and its branches distally from the aneurysm, and later, the absorption of the adjoining tissues from the pressure of the aneurysm (Fig. 447).

FIG. 447.—Sphygmographic tracings of the radial pulse of a patient with aneurysm of the right brachial artery: 1, left radial pulse; 2, right radial pulse (Mahomed).

Etiology.—The immediate cause of the development of an aneurysm is usually an injury to a previously diseased vessel. This development in the majority of cases is due to the suddenly increased blood-pressure from a violent muscular exertion or a sudden strong emotion.

The predisposing causes of aneurysm are some constitutional dis-

ease or habit which by its long continuance has either attacked the arterial coats in distinct areas or has caused such general and extensive degeneration as to have decreased to a large degree the elasticity and resisting powers of the arterial walls. Degeneration of the arterial coats is the chief predisposing cause of aneurysm, and it must always be present in some form, except in those cases due to direct traumatism. Suppurative disease occasionally invades the wall of a vessel, and is said to give rise to aneurysm.

It is a recognized truth that the existence of arteriosclerosis is the chief factor in the causation of aneurysm, and while this disease does not manifest itself till late in life, it exists in the diffuse stage as early as forty years—the most common time for aneurysm to develop. As a rule, patients ascribe the cause of aneurysm to some severe muscular effort, which is but natural.

As a rule, aneurysms contain fluid blood, which readily transmits the pulsations of the heart through its walls. In certain cases, however—for example, in sacculated aneurysms, where the outlet is small and the blood-current is much reduced in force—the blood coagulates and is deposited in successive laminæ upon the wall of the vessel, forming yellowish thrombi which greatly strengthen the wall of the sac. If an aneurysm is left to its natural course, with very rare exceptions it proves fatal. The sac continues to dilate more or less rapidly, and death takes place from rupture of the sac, with fatal hemorrhage either externally or into some one of the cavities of the body. In certain instances death occurs before the sac ruptures, owing to pressure upon important organs, with correspondingly severe symptoms—for example, on the trachea and bronchi, producing asphyxia; on the esophagus or thoracic duct, producing inanition; on the spine in aortic aneurysm, causing absorption of the bone and meningitis. The final rupture may or may not be due to muscular strain; death is not always instantaneous, but frequently occurs after several successive hemorrhages.

The **prognosis** of aneurysm of the aorta, the innominate, the subclavian, and iliac arteries is usually fatal, although a few cases of cure have occurred in aneurysms situated in these vessels. The gravity of the disease decreases and the success of operative interference increases as the location of the trouble is removed from the heart. The duration of life in aneurysm varies within considerable limits according to the condition, occupation, and care of the patient, as well as the location of the disease.

Treatment.—All methods of treatment of aneurysms are directed toward obliterating the cavity by coagulation of blood within its sac. They have been classified as medical and surgical. The former comprise those which by rest in bed, restriction of food and liquids, and administration of drugs aim to prevent increase in the size of the tumor and favor coagulation of the blood, by reducing the force of the blood-current. These methods have been in use for a very long time, but are now employed only in those cases of internal aneurysm in which operative methods are contra-indicated. The details of the treatment, as proposed by Tufnell, are absolute rest in bed, a dry diet composed of a very few ounces of bread or farinaceous food, with a very little

fish or meat once or twice a week, together with a few ounces of milk or water daily. A number of cures have been reported from this course of treatment, which requires great resolution and courage on the part of the patient to persist in for the necessary length of time, which is usually two to three months. An ice-bag or pressure may be applied to the tumor itself. Belladonna, aconite, and veratrum viride are used to assist in reducing the force of the heart's action. Symptomatic treatment is necessary in almost all cases; for pain, the bromids, phenacetin, and opium are used when necessary. For attacks of angina amyl nitrate, nitroglycerin, and barium chlorid are indicated. Iodids are administered, not alone for their effect on syphilis, but because they are supposed to have a direct action on the arteries; and it is claimed that the tincture of iodin and the sodium salts are better than the potassium salts. Potassium iodid in increasing doses is most frequently administered, and in some cases a cure has been apparently favored by its action. It is supposed to slow the action of the heart, to lessen its force, and to thicken the walls of the aneurysm by the deposition of fibrin. For the purpose of inducing the coagulation of blood in the aneurysm, injections of solutions of iron, ergot, tannin, and other drugs are sometimes made into the sac; but there is great danger of the formation of emboli attending this method of treatment, and it therefore should be condemned.

Acupuncture consists of the introduction of several needles into the cavity of the sac, allowing them to remain several hours and then withdrawing them. This favors coagulation, but it is not without danger.

Galvanopuncture is performed by inserting an insulated needle from either side of the sac, and with the needles in contact a galvanic current is passed through for several hours. This method is open to the same criticism as the preceding measures.

A more recent method devised by Macewen, known as "*needling*," has for its object the formation of a white thrombus on the inner surface of the sac. It is accomplished by introducing under aseptic precautions long steel needles, and gently irritating with their points the entire inside lining of the tumor. The irritation should be only great enough to produce a reparative exudation, so that there is formed by successive needling a permanent thickening of the walls of the aneurysm. Two or three needles are used at the same time in a large aneurysm, and a number of foci of repair are distributed over the interior of the aneurysmal sac. It is especially applicable to large sacculated aneurysms which are inoperable—for example, those situated at the arch of the aorta. Cures have been reported by Macewen.

The introduction of foreign bodies into the aneurysmal sac through a cannula after puncture is another method of treatment for large inoperable aneurysms. Fine steel wire, horse-hair, catgut, and silk are the materials which have been used. A number of yards of the wire or other substance is introduced through a pointed cannula in the hope of causing obliteration of the cavity by an engaging blood-clot. A number of cases treated in this manner have been reported, but very few successes have occurred. The method is a dangerous one, and only to be used as a last resort.

Compression.—The treatment of aneurysm by compression is perhaps the oldest form of treatment, and, when properly carried out and persisted in for a sufficient length of time, usually results in improvement, and often in cure. The pressure is applied preferably to the cardiac side of the tumor, and may be digital or mechanical.

Digital pressure is more rapid and less painful than mechanical, but it is an extremely difficult thing to keep it up for the necessary length of time, which may be twenty-four to forty-eight hours, with firm uniform pressure under an anesthetic. A relay of assistants is necessary in carrying out this method.

The use of *mechanical* or *instrumental compression* is not advised. The method by digital compression, while annoying and painful to the patient, especially if he be irritable and cannot bear pain well, is a very safe method of treatment, and no great risks are involved in case of failure. Under modern aseptic technic the method of digital compres-

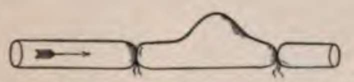

FIG. 448.—Old operation of Antyllus for aneurysm (Keen and White).

FIG. 449.—Anel's operation for aneurysm (Keen and White).

FIG. 450.—Brasdor's operation (Holmes).

FIG. 451.—Wardrop's operation (Holmes).

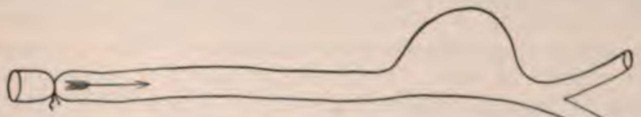

FIG. 452.—Hunter's operation for aneurysm (Keen and White).

sion has been lately superseded by direct operative measures (Figs. 448–452).

Treatment by Ligature.—The treatment of an aneurysm by direct ligature to the vessel is unquestionably the most satisfactory method when the aneurysm is situated so that this can be accomplished. The operation must be performed under the strictest aseptic precautions, the

material being either silk or animal ligature, and the wound closed to secure primary union. Sepsis, secondary hemorrhage, and gangrene are the chief dangers to be feared as the result of operation. Several different operations are in use—namely, the distal ligature, the proximal ligature, and the double ligature. The most common method in use at present is to ligate the artery on the proximal side at some distance from the tumor, in order that a place which is firm and free from disease may be secured. The double ligature of the vessel, with excision of the sac (Antyllus), is the best operation. Distal ligature may be necessary on account of the situation of the disease, as when it occurs in the innominate or subclavian arteries. The advantage of ligation over other methods of treatment is its applicability in a greater number of cases, the greater likelihood of success, its comparative ease and safety, and its painlessness.

Aneurysm of Special Vessels.—Aortic Aneurysm.—Aneurysm of the aorta may occur at any point in the chest or abdomen, but those involving the arch of the aorta are the most common. The disease is usually obscured until the dilatation has advanced to a point where the tumor is visible externally, or until the pressure-symptoms are so acute as to make the diagnosis possible. A pulsating expansile tumor of a very large size in the front of the upper part of the chest, more often on the left of the sternum, is characteristic of an aneurysm of the aortic arch. The very early symptoms are more or less constant pain, disturbance of the laryngeal muscles from pressure on the recurrent laryngeal nerve, causing interference with respiration, interference with deglutition, and changed voice-sounds. Retardation of one radial pulse and dilatation of the pupil on one side are occasional symptoms. As the tumor increases, the symptoms become more severe; pain, loss of sleep, cough, and anxiety supervene. Absorption of the contiguous tissues of the sternum, ribs, and vertebræ takes place, and death results from an external rupture or more frequently from an internal rupture of the aneurysmal sac. The *treatment* of aneurysm of the aortic arch offers little hope of success. A few cases have been reported of a successful result from Macewen's method, and also from the introduction of foreign bodies into the sac.

An **aneurysm of the abdominal aorta** is rarer than one of the thoracic aorta. The development of a characteristic pulsating tumor, with the presence of the aneurysmal bruit in the abdominal cavity, and the careful exclusion of tumors of the other abdominal organs, is the way in which a diagnosis may be established. The treatment offers very little chance of cure. Pressure by means of a mechanical tourniquet may be applied, if the location of the tumor renders this possible. The abdominal aorta has been ligated a number of times—always, however, with a fatal result.

An **aneurysm of the iliac arteries** presents the same symptoms as an aneurysm of the abdominal aorta, except that being situated lower in the abdomen it may be made out more clearly. The abdominal aorta has been ligated a number of times for iliac aneurysms. The common iliac artery has been ligated several times with success, and although this is a critical operation, it promises relief.

Femoral Aneurysm.—The diagnosis is comparatively easy, but

from the exposed position of the vessel the aneurysm is often of traumatic origin, and hence may be a false aneurysm. It may for this reason be mistaken for a psoas or inguinal abscess, and care must always be exercised in operating in this region in excluding an aneurysm. A femoral aneurysm has been incised for a psoas abscess with fatal results. An aspirating needle can always be used in case of obscure diagnosis, and the problem in this manner solved. Proximal ligation of the artery is the best operation in femoral aneurysms.

Popliteal aneurysm is one of the more common types of the disease. Owing to the location of the artery it is peculiarly liable to be injured, especially by extreme flexion of the leg; and if the vessel has become weakened by pathological changes, it may readily become subject to aneurysmal dilatation (Figs. 453, 454). The tumor is necessarily

FIGS. 453, 454.—Popliteal aneurysm.

superficial in position, and therefore the diagnosis is easy because of the characteristic symptoms. Proximal ligation at the apex of Scarpa's triangle or at Hunter's canal, or preferably double ligation of the artery with excision of the sac, are the methods of treatment.

An **innominate aneurysm** is usually complicated by a dilatation of the arch of the aorta, and often of the subclavian and carotid arteries. The tumor usually appears above the sternum, in the interclavicular notch, or to the right, near the origin of the sternomastoid muscle. Owing to the short course of the innominate artery and on account of its location, the aneurysm is usually a sacculated one, and

for this reason a ligature can rarely be applied on the cardiac side of the aneurysm. For innominate aneurysms several operations have been performed—distal ligation of the subclavian artery, ligation of the right common carotid and the right subclavian arteries, or the ligation of either. All of these are very serious and grave operations, but cures have been reported from the use of each. The innominate itself has been ligated in all 30 times, and usually for subclavian aneurysm. Only 4 of these cases are reported as recoveries. The important step in ligating the innominate artery is the excision of the upper portion of the sternum, which renders an otherwise difficult operation a comparatively simple one. The operation under improved technic is entirely justifiable.

Subclavian aneurysm is most frequent in the outer or third part of the vessel and on the right side. It develops as a pulsating tumor above the clavicle and outside the sternomastoid muscle. It gives rise to disturbance by pressure on the brachial plexus, and it may cause edema of the arm and hand. Ligature of both the proximal and distal sides have been performed, besides ligation of the innominate. Ligature on the proximal side of the vessel, followed by immediate amputation at the shoulder-joint, has been suggested.

Axillary aneurysm is frequently of traumatic origin, and occasionally occurs as the result of an attempt to reduce old dislocations in a patient with atheromatous arteries. It often attains large size from looseness of the surrounding tissues, and by pressure causes venous obstruction and edema, and threatens the loss of the whole limb. The axillary artery is rarely ligated except where it is wounded or for a small traumatic aneurysm. The operation for idiopathic aneurysm of the axillary artery is the ligation of the third portion of the subclavian artery. If there is a recurrence of pulsation in the aneurysm, the distal ligation of the axillary artery and, if necessary, excision of the sac are indicated.

Carotid aneurysm may occur at either side of the neck, and is usually situated near its bifurcation. The symptoms are the typical pulsating tumor, dyspnea, vertigo, difficulty in swallowing and talking, cough, and ringing in the ears. The diagnosis is usually not difficult. Ligation on the cardiac side of the common carotid is the best method of treatment when possible; otherwise, distal ligature. Syncope, embolism, and hemiplegia occasionally occur following ligation of the vessel. There are cases on record, however, in which both common carotids have been ligated in the same person successfully.

CHAPTER XXVIII.

SURGERY OF THE LYMPHATIC SYSTEM.

THE lymphatic system may be likened to a series of canals (lymph-vessels), reservoirs (glands), and lymph-spaces. The lymph-spaces are simply channels in the intercellular substance. Of their embryonic origin but little is known. For purposes of illustration, if we consider each of the larger canals as supplied by an infinite number of small feeders commencing in a *cul-de-sac*, an approximate idea may be had of the nature of the lymphatic system. Now, if we consider that these *cul-de-sac* feeders and the main lymph-channels are so numerous in the body, especially on the surface of the body, that the finest cambric needle cannot pass between them without wounding, we can then

FIG. 455.—Valves of a lymphatic vessel (after Beaunis et Bouchard).

FIG. 456.—Vertical section of a villus (after Stewart): *a*, layer of columnar epithelium covering the villus; the outer edge of the cells is striated; *b*, central lacteal of the villus; *c*, unstriped muscular fibers; *d*, mucin-forming goblet-cells.

imagine something of the vast importance of the lymphatic system to the body in general, both in health and disease. If these lymph-canal feeders were not, like the parent trunk, supplied with valves, the infections would be much earlier received into the system and be more serious; but owing to the slight resistant action of the valves in the lymphatics, which are more numerous than the valves in the veins, and are universal in lymphatic vessels (Fig. 455), they easily become obstructed by reason of irritative changes, and poisonous material or

microbes are kept out of the general system. This applies to all of the cutaneous lymph-capillaries.

Of the intimate structure of the lymphatic vessels, we find that the anatomy is practically identical with that of the venous system. It is a tunica intima composed of a bed of fusiform epithelial cells, a middle tunic of feeble muscular fibers mixed with fine elastic fibers, and an external tunic or adventitia, which is formed of longitudinal connective fibers. The glands or reservoirs are not mere continuations of the tubular vessel, but are alveolar structures communicating one with the other—a true parenchyma consisting of cells surrounded by a screen of the finest network. This reticulated network structure forms the periphery of each alveolus. The alveolus itself has been called the sinus lymphaticus, and with the contents has been collectively spoken of as a central pulp (Fig. 456). Large serous membranes, such as the peritoneum, have open communication with the lymphatic vessels—that is to say, they constitute one method of commencement of the lymphatic vessels, which in that case depart from the rule of *cul-de-sac* commencements. The afferent vessels coming to the gland are seen to enter it at any part of its periphery, and they open into the lymph-sinuses or the cortical portion of the gland. Likewise the efferent vessels commence from the lymph-sinuses of the medullary portion of the gland. The blood-vessels are supported by trabeculæ, and although Kölliker has described the nerves entering the hilum of the gland, the nerve-fibers have not been demonstrated on the trabeculæ (screens), although they doubtless exist. The stream of lymph, then, as it is gathered by the vessels is brought to the glands, and is retarded in its passage by the trabeculæ through which it must pass. Any consideration, then, of the diseases of the lymphatics must necessarily take into account, in a general way, the anatomy and function of the vessels and glands. We must naturally consider the normal fluid of the capillary vessels, and the fact that a large part of the constituents of the blood, instead of passing back to the heart from the capillaries along the veins, must pass along the lymphatics, as the blood-capillaries are everywhere in intimate relation with the lymph-capillaries, and that the contents of these again finally find their way back to the heart through the thoracic duct.

The rate of flow of lymph to the heart is very slow, only about 4 millimeters (.15748 in.) per second, although in the beginning it is more rapid, corresponding with the rate of the flow in the capillaries themselves. This flow varies, too, according to the muscular pressure and movements of the limbs, either active or passive, and to the force of gravity. The movements of respiration also aid the flow in the lymphatics. Venous obstruction, by producing edema, either local or general, increases blood-pressure in the capillaries and the transudation through the capillaries. It is true that certain substances may be injected into the blood, and thus, without affecting appreciably the arterial pressure, may increase the flow of lymph. These substances are called "lymphagogues." It may be stated, however, as a general proposition that blood-pressure affects the lymphatic flow only in a secondary and indirect manner.

Finally, it is to be remembered that the age of the patient has much

to do with disease of the lymphatics, as the lymph or juices of the body are more abundant in infancy and youth than in old age, and the changes are carried on more rapidly.

THE SPLEEN.[1]

Surgical affections of the spleen may be arranged in four principal classes—namely, traumatic lesions, displacements, parasitic diseases, and tumors.

Wounds of the spleen are of the usual classes—punctured, incised, and lacerated wounds. Where these occur to a large extent, they are speedily fatal from excessive hemorrhage. In military surgery, bayonet wounds and gunshot wounds are the most frequent causes; in civil life, accidental causes and ruptures. In malarious districts enlarged spleens have been ruptured by accidental blows, kicks, or injuries received on the abdomen over the spleen, frequently without external sign. The author has seen one fatal case of rupture of the spleen where a man, living in a malarious district and the subject of enlarged spleen, was kicked by another while in a brawl. The patient died within two hours after the injury. Post-mortem examination showed a transverse rupture of the spleen, with escape of blood into the abdominal cavity. The symptoms in such cases are usually those of concealed internal hemorrhage. Rupture of the spleen during labor was observed by Hubbard in 1879.

Of uncomplicated wounds of the spleen, the statistics of Meyer show 2 recoveries out of 5, and those of Otis, 2 out of 4. Abinese found a case on the seventeenth day with a wound of the spleen, the patient having died of general peritonitis, where the cicatrix was 7 centimeters ($2\frac{3}{4}$ inches) long, and the wound had penetrated into the substance 3 centimeters ($1\frac{3}{16}$ inches). Bahan reports the case of a French soldier, wounded at Sebastopol, who died with nephritis seven years after the wound. He found a portion of the bullet in the spleen. The dangers of these wounds are from hemorrhage and from infection. The **treatment** therefore consists in laparotomy, which should be performed as soon as the diagnosis has been reached. Arrest of hemorrhage by ligature is not possible, but direct hemostatic pressure with iodoform gauze is indicated. Where there is hernia of the spleen, owing to a wound of the abdominal parietes, it should be reduced, and the wound sutured, if practicable; but if the hernia is not reducible, galvanocautery to the edges of the wound should be made, or the thermocautery applied, in order to secure adhesion between the lips of the wound and the protruding spleen, after which the portion of the organ protruding may be included with the ligature. Olshausen recommended elastic ligature in these cases. Kuchenmeister separated the projecting spleen with the thermocautery.

Displacements of the spleen are usually traumatic. In a case reported by Verga, after a blow received in the left side from the pole of a vehicle, the spleen was found in the left iliac fossa. The spleen is also displaced from hypertrophy in the progress of various diseases which need not here be referred to.

[1] See also Vol. II., Chap. XIV.

The **differential diagnosis** between displacement of the spleen and of the kidney presents some difficulty, and must be made by bimanual palpation.

Treatment consists in palliative measures, as the wearing of an appropriate truss, splenopexy, or ablation.

Splenitis.—Splenitis from infectious diseases may occur as either a primary or a secondary affection. Primary tuberculosis of the spleen is somewhat rare, as are other primary pyogenic infections of this organ. The writer has seen a case evidently of primary tuberculosis of the spleen in the Presbyterian Hospital, Chicago, in which the spleen had attained an enormous volume and was painful and tender to the touch. The edge of the spleen could be felt on the right side of the linea alba, and the lower left iliac fossa was entirely occupied by a dense mass which finally fluctuated. An incision was made and the capsule exposed, but it was found impracticable to remove it, owing to the density and strong posterior adhesions. An incision was therefore made in the capsule, the tuberculous matter evacuated, and at the same time a large portion of the inflamed mass turned out with the fingers. The wound was thoroughly cleansed with iodin-water and packed with iodoform gauze. The hemorrhage was very slight, and the temperature, which had been high, fell immediately after the operation to a normal point. The dressings were changed daily for a period of about three months, but the patient became greatly emaciated and died. Tubercle bacilli were found in the substance of the spleen during the life of the patient, leaving no doubt as to the diagnosis.

While **abscesses** following traumatism may occur without an open wound, they are extremely rare, and even in military surgery it is found, as a rule, that the subjects of splenic abscesses have previously been attacked by infectious or paludal disease. These abscesses may open through the diaphragm into the pleura, the stomach, the descending colon, the vagina, splenic vein, or peritoneal cavity.

Grand-Moursel has compiled a table of the relative frequency of these different points in 57 cases.

Splenectomy has been practised in these cases by Billroth, Meyers, and others, but the operation has not been generally followed by success, as in the majority of cases septicemia is well under way before the abscess reaches that stage of development when its recognition is certain.

Hydatid disease of the spleen is very uncommon, but in those countries where echinococci are found, cases have been reported. The only means of making a differential diagnosis between hydatid and other cystic tumors of the spleen is by puncture and examination of the enclosed fluid, where the hooklets of the hydatid can be found. After a diagnosis has been reached by puncture, an incision should be made over the center of the tumor parallel with the twelfth rib, and the cyst-wall attached by suture to the peritoneum. In five or six days ignipuncture should be made, evacuating the contents of the cyst and packing the cavity with iodoform gauze, renewing the dressing from time to time until the wound heals.

Neoplasms.—The tumors of the spleen are lymphadenoma, fibroma, epithelioma, and sarcoma. **Lymphadenoma** of the spleen is

usually an accompaniment of leukemia, and is attended with the usual symptoms of that affection and similar enlargements of the lymphatic glands of the liver and of other organs. The symptoms of leukemia are always manifest, which consist in alteration and diminution of the number of red blood-corpuscles, with great increase in the number of white blood-corpuscles. The disease, as will be seen further on, is progressive and fatal. Splenectomy for the enlarged leukemic spleen has been practised, but the operations have invariably been fatal. Jonnesco has performed splenectomy for the hypertrophied spleen of malaria with success, and believes it to be the proper treatment for chronic relapsing cases. **Fibroma** of the spleen is usually congenital, and is very rare. In **sarcoma** of the spleen we find the tumor springing from the capsule, and sometimes from the trabecular fibrous structure. It is very vascular, grows to an enormous volume, and is uniformly fatal. It is inoperable except in the early stage. **Epithelioma** of the spleen is also extremely rare. Nineteen cases have been collected by Besnier. In these cases the normal splenic tissue disappears and is replaced by epithelial cells proliferating in the alveoli.

In all cases of splenic tumors, when the diagnosis is made early, splenectomy should be the rule. Péan made the suggestion that in the performance of splenectomy the ligature should be placed as far away from the hilum as practicable, and then seized by a hemostatic clamp before cutting the pedicle. The clamp should remain in place for twenty-four hours.

Anomalies.—Several observers have found the spleen deficient or wanting. Supernumerary spleens have been reported, and several cases of multiple spleens are on record.

THE LYMPHATIC VESSELS AND GLANDS.

Inflammation of Lymph-glands.—Angioleucitis and lymphangitis are terms applied to inflammation of the lymphatic vessels as a result of the introduction into their channels of irritant chemicals or microbes; a sunburn, or electricity in the form of the Röntgen rays has also produced it. Almost any of the ordinary causes of inflammation of the skin are manifested by the lymphatics, and the most usual source is an abrasion of the skin or puncture which removes the epidermis, as in the case of persons handling hides, those engaged in dissections, surgical operations in cases where septic material exists, or persons engaged in handling decomposed tissues. The inflammation begins with the usual symptoms of inflammation, such as redness, heat, swelling, and pain in a small area, and these signs gradually extend toward the body in the line of the lymphatic vessel. Sometimes, so rapid is this transmission that the outline of the vessel can be seen distinct from the surrounding tissues by its redness, which increases and finally extends to the nearest lymphatic gland. When the gland is reached, that body becomes at once swollen and tender, and if the microbic invasion be sufficient, active inflammation is set up in the trabeculæ of the gland, and suppuration follows. The patient is fortunate if the inflammation ends here; but not infrequently at this stage constitutional symptoms are developed, manifested by fever, rigors, and

all the evidences of septicemia. Where the temperature is marked by a sharp rise, metastatic abscesses may develop in internal organs or in the lymphatics quite remote from the original point of infection. Where a gland becomes infected in the groin as a result of invasion of the gonococcus or the bacillus of Lustgarten, it is termed a bubo, and the primary disease does not usually extend further. The reason for the stoppage of the infection by the gland is owing to the closure of the efferent vessel in the medullary substance by adhesion of the endothelium and complete obstruction of the efferent vessel itself.

Lymphangitis as a secondary affection is seen after diphtheria, scarlet fever, typhoid fever, typhus, and is constant in bubonic plague. Lymphangitis produced by the streptococcus of erysipelas will be referred to elsewhere under that head. The lymphatics play an important part in the diffusion of carcinoma, differing in this respect from sarcoma, which is transmitted by the veins.

Treatment.—The treatment of lymphangitis should be immediate and directed to the cause of the affection. Chemical antiseptics should be applied at once to the skin at the original point of invasion. A solution of carbolic acid, bichlorid of mercury, aluminum acetate, or boric acid, with the dressings frequently changed, is among the favorite applications. If the gland is much swollen and remains hard, the injection of a 5 per cent. solution of carbolic acid will frequently allay the symptoms. Injections of alcohol have also been practised. The induration of the lymphatic gland may remain for a long time, the microbes apparently remaining latent in the gland. Years may elapse before the normal size of the gland is reached. When the gland proceeds to suppuration, however, the pus should be promptly evacuated or the gland excised. Evacuation of the pus and subsequent drainage are usually followed by prompt recovery.

Tuberculous Lymphangitis.—Tuberculous lymphangitis may be seen in any of the glands of the body, especially of the intestine and glands of the neck. The onset of the affection is slow. The exact method of invasion is not well understood, as the first symptom of the affection is usually swelling of the superficial glands, which may be felt just under the skin as hard, firm, and not very painful bodies. As the disease progresses the swelling is more pronounced, the gland becomes larger and more painful, and in some cases pressure-effects are noticeable. The enlarged glands connected with certain groups—those just anterior to the sternocleidomastoid muscle, for example—will be found to involve the entire chain of lymphatics in this region. The writer has removed as many as thirty at a single operation, all connected, and varying in size from a coffee berry to that of an English walnut. Left to themselves, there is a tendency for the disease to spread through the vessels to adjacent lymphatics until both the superficial and deep lymphatics of the neck are implicated. Then, when the inflammation becomes sufficiently acute, the larger glands fluctuate, suppuration becomes established, and the abscess points; or in some cases, where the skin is not broken, the liquefied tubercle burrows deeply in the neck, sometimes extending to the thoracic cavity, and the life of the patient is finally involved, disseminated tuberculosis, in which miliary tubercles are found in the lung and elsewhere, ushering in a fatal result.

Treatment.—Tuberculous glands of the neck should be removed by operation as soon as a diagnosis is made, before very extensive involvement of the adjacent glands has occurred. In these cases it is usually necessary to divide the sternomastoid muscle, turning the ends out of the wound, so that the chain of glands may be removed in its entirety. Care should be taken during the operation that none of the tuberculous matter is left in the tissues. Whenever practicable, the glands should be removed from below upward, and when the mass has been separated as far as the jugular fossa, it should be seized and twisted off at its upper attachment. After the operation the ends of the divided muscle are brought together with strong catgut suture, and the wound closed with silkworm-gut. Cod-liver oil internally and guaiacol should be persevered in for a long period.

Hodgkin's Disease; Lymphadenoma; Pseudoleukemia.—This is to be distinguished from leukemia by the examination of the blood, which is normal. The disease is seen frequently in childhood, and usually begins in the neck, the whole chain of glands becoming involved, and finally the adenoid tissue throughout the body, the axillary glands, and glands in the groin being particularly noticeable. There is no pain in the swollen glands. If, however, a section is made of one of them, it is found that the trabecular structure is largely lost, and is replaced by lymphoid cells. In certain cases the fibrous structure seems to be increased, in which event the glands become hard and firm. Death usually occurs with some manifestations of leukocytosis, diarrhea, or general anasarca from lymphatic obstruction.

Lymphadenoma of the Bones.—In 1866 Ranvier described the lesions in the pelvis of a child of ten years, and Perier in 1884 saw a case in the inferior maxilla in a patient twenty-four years old. These were also accompanied by multiple lymphatic tumors in the spinal column, in the ribs, and in the tibiæ. Lannelongue and Broussais have also described osseous lymphadenoma which developed in young subjects, and is seen in two different forms. In one series of cases the subjects are leukemic, and the lesions are diffuse in the medullary cavities. In the second variety they are seen as tumors and distinct masses, accompanied by leukocytosis, and often by true leukocythemia. All the cases so far reported have died. The diagnosis from osteosarcoma was made by the presence of the leukocythemia, which is absent in the latter case.

Treatment.—Treatment, either medical or surgical, has heretofore been of little avail. The use of thyroid extract, which has proved so effective in certain cases of bronchocele and in myxedema, has been suggested, and from what is known of its excellent results in myxedema it would seem to be worthy of further trial.

Lymphangioma.—In this disease the plexiform vessels are lymph-vessels instead of blood-vessels. We have the same divisions as in angioma—that is, (1) capillary, (2) cavernous, and (3) cystic. In the capillary variety the tumor is composed of lymph-spaces and lymphatic vessels. The cavernous variety consists of dilated spaces containing lymph, communicating with each other. Capillary lymphangioma is congenital always, and the cavernous and cystic varieties may be congenital, but usually develop after birth. The capillary form is some-

times termed lymphatic nevus. In the cystic form of lymphangioma the affection is formed probably by the obstruction of a single lymphatic or by the dilatation of a single space, which, extending to others, obliterates the trabeculæ, and finally forms a single cyst, the walls of which consist of fibrous tissue lined with epithelium containing lymph.

Cystic Hygroma.—This is a congenital disease arising from a defect of the lymphatics. It occurs most frequently in the neck—

FIG. 457.—Cavernous lymphangioma of neck and axilla in a young woman (Homan's case).

when it is termed hydrocele of the neck—in the axilla or on the back, and occasionally in the region of the kidney (Treves). It springs from the lymphatics, from beneath the deep cervical fascia, and may be present on either side of the mastoid muscles. Sometimes these cysts are connected with the branchial clefts, and then cannot be distinguished from ordinary branchial cysts. The **treatment** is excision of all of the tumor that can be excised, under antiseptic precautions, packing the wound with iodoform gauze, and allowing it to close by granulation.

Macroglossia.—Several affections have been designated under

the general term of macroglossia, but here we shall refer only to those having lymphatic origin. They may be congenital or develop later. Butlin has recognized the causes as mostly local, such as abscess, ranula, salivation, or wounds; general causes, such as those resulting from small-pox, scarlet fever, diphtheria; and traumatic causes, biting of the tongue by epileptics, etc. These point unfailingly to a microbic origin. However it may exist, it is found that the lymphatic vessels are dilated, and for the most part it is observed as a cavernous lymph-angioma, sometimes as serous multilocular cysts. In the beginning the tongue commences to increase in size until it becomes so large that it protrudes from the mouth, when the normal aspect of the tongue is entirely changed by the drying of the mucous surface and the thickening and enlargement of the papillæ. Mechanically, the lower jaw becomes affected after a time until it is finally dislocated. Respiration is little affected, and the swallowing of liquids can be performed; but the taste becomes lost, and the mastication of solid food is impossible. Diagnosis offers little difficulty.

Treatment.—Compression has been tried without avail. Deep ignipuncture has been practised by Helferich, but amputation is about the only remedy. This may be practised by excising the thickened tongue in V-shape, bringing the flaps together in the center with deep sutures of silkworm-gut or silver wire. The danger in all cases of operations here, as elsewhere about the mouth, is from infection. There is no known means of absolutely preventing it. Frequent paintings with alcohol over the line of incision are advisable. The sutures should be removed before suppuration takes place, as invasion by mouth bacteria is almost certain. Though the results are satisfactory, the complications will require treatment. Sometimes the removal of the teeth and the replacement of the lower jaw are effected with much difficulty. Division of the neck just below the condyle has been recommended.

Macrocheilia.—This is a congenital lymphangioma of the lip, followed by great hypertrophy, with growth sometimes extending to the cheek It continues to increase with the growth of the patient. The swelling is not very compressible.[1]

The diagnosis from tuberculosis is made by attention to the history of the case and a section of the tumor. Tuberculosis of the lip is rarely, if ever, congenital, and by examination with a low power the lymphatic capillaries can be demonstrated. Excision of the whole mass is the only remedy.

Elephantiasis is a condition of hypertrophy of the skin and subcutaneous tissues, usually held to be due to obstruction of the lymph-channels. In its typical form it is endemic in certain tropical and subtropical regions, where it is definitely known to be the result of the entrance into the system of a parasite, the Filaria sanguinis hominis of Lewis. This, according to Chemin, was first detected in the human fluids in 1863 by Demarquay, who found it in a hydrocele, and since then, by the studies of Wucherer, Lewis, Bancroft, Manson, and others,[2] it has become more thoroughly known, and its life history and connection with the condition in question have been fully elucidated. The parasites are

[1] See Vol. II., Chapter I. [2] See Chapter IV., on the Pathology of the Blood.

found to abound in the lymphatics, and the most accepted theory of their action is probably that which attributes the obstruction of these vessels to their large hemispherical ova, while the elongated animals themselves are less probably the cause of the lymph-stasis. Their introduction into the system is commonly supposed to be through drinking water.

FIG. 458.—Lymph-scrotum (Fiji Islander); elephantiasis; ninety pounds.

The usual clinical picture of elephantiasis is, in its incipiency, that of febrile paroxysms attended with great suffering, nausea, pain in the lumbar regions, groin, scrotum, etc., followed by chyluria and severe congestion and swelling of the parts. As the disease progresses, the limb or other regions involved become enormously enlarged, the scrotum or labia alone, in some instances, weighing over one hundred pounds. The parts are infiltrated with a lymphoid fluid which oozes from the cracks and fissures in the thickened and rugose epidermis. As strict cleanliness is difficult or impossible, the growth becomes fetid and offensive, and while, with the enlargement, sensibility is dulled or lost, the condition is a miserable one and life is a burden (Fig. 458).

The disorder is endemic in various parts of the world—South America, the West Indies, Africa, India, Australia, and elsewhere—and it is said to be not infrequent in some of the southern states of America, where it is probably due to the same cause as elsewhere in warm regions.

A *false* or *non-parasitic elephantiasis* is occasionally observed, more or less closely resembling the true tropical disease, and has generally been ascribed to lymphatic obstruction. It has been observed after gonorrheal lymphangitis or syphilitic disease, and congenital cases have been described, in some instances apparently associated with hereditary specific infection. According to Haferkorn,[1] such cases of lymphangitis with lymphorrhagia, passing gradually into a form of elephantiasis (*elephantiasis mollis*), and not connected with filarial disease, are often due to congenital defects analogous to those producing varicose veins. The disorder is due more to stasis from weakness and dilatation of lymph-channels than to their actual obstruction.

[1] *Deutsche Arch. für klin. Med.*, No. 56, p. 402.

The **diagnosis** of true tropical elephantiasis is approximately reliable from the history and symptoms in any individual case, but is rendered certain only by the finding of the parasite or its embryo. The **treatment** is limited to change of residence in the earlier stages from the tropics to a colder climate, and, later, surgical interference may be almost the only resource. This is often effective where the disease is confined to a limb or other part that can be completely amputated, like the scrotum, but there is a degree of uncertainty as to this, for it may be that not all the parasites are removed, even in extensive amputations. Medical treatment is not encouraging as to the removal of the disease, though some success has been claimed from the use of methylene blue, which is said to be readily taken up by the filarial cells, and is fatal to the parasites. Aside from this, general treatment must be limited to attention to the general health, the excretions, the use of tonics, and anodynes to relieve pain. The disorder does not directly threaten life, but it makes it a burden to the patient and offensive to those about him.

Chyluria, when not associated with traumatism, parasitic disease, or other extensive obstruction of lymphatics, is rare, and its cause is generally obscure. The simplest cause of non-parasitic chyluria would be a traumatism connecting the lymph-channels with the urinary passages, and the possibility of abnormal dilatation and weakness of lymphatics in the vicinity of the urinary tract is also to be considered. It is often irregular in its appearance in these cases without apparent cause. Aside from the possibility of its causing retention of the urine from lymph-coagulation in the bladder, which can be relieved by repeated injection and withdrawal of a warm solution of sodium bicarbonate, this symptom by itself rarely causes any serious inconvenience.

Lymph-fistulæ with lymphorrhea are generally the results of wounds or ulcers. They may be due to the opening of enlarged and suppurating glands, to the removal of tumors, to compound fractures, or be accidentally produced by the operation of phlebotomy. If there is already a condition of enlargement or relaxation of the lymphatics, their production is facilitated.

Ordinarily, they occur in the neighborhood of joints, such as the axilla, the groin, the elbow, etc. If not very large, they cause little trouble other than from the moisture of the part caused by the constant oozing. This may be an inconvenience when treatment for closure fails.

When occurring as a complication of compound fractures, there is liable to be a condition of severe nervous shock and depression of the vital powers, which I have been led to consider as directly associated with this accident. The condition is more or less persistent, and may seriously embarrass the prognosis. Indeed, a fatal result is not uncommon.

In recent cases compression will often be sufficient treatment, the pressure being applied below or over the wound, preferably the former, as the latter may cause edema or abscess.

When nervous depression is marked, besides local treatment, elevation of the part, massage, etc., with vigorous stimulation, are required to meet the condition.

Rupture of the thoracic duct, though a rare accident, may follow contusions of the chest, punctured or gunshot wound, suppurative or ulcerative disease, and may occur sometimes from causes not apparent. It may also be involved in operation in the region of the neck, as the arch of the duct has been observed as high as two inches above the sternum and touching the thyroid gland, and this possibility should be kept in mind in case of surgical procedures in the lower cervical region. It may be caused also by back pressure from obstruction more centrally situated. In any case, and whatever the cause, it is a more serious matter than wound or rupture of the more peripheral lymphatics. Unless some anatomical condition exists that can render possible a collateral lymph-circulation, or spontaneous healing takes place, death is probable within a longer or shorter period, from inanition. The chylous extravasation may also itself give rise to serious consequences in compression of the lung (chylothorax) or chylous ascites. It is probable that in many cases a collateral circulation is possible, as suggested by Welch, who says that he has seen the thoracic duct completely occluded without serious interference with the flow.

Treatment.—Keen,[1] Boegehold,[2] and Phelps[3] have also shown that surgical interference may be successful in this accident. In Keen's case suturing of the duct resulted in a cure in eight days. Even after extensive chylothorax, recovery may spontaneously occur if the fluid is evacuated (Kirchner).

Boegehold, on the basis of experiments on dogs and some clinical observations, appears to think that closure of the duct is not necessarily fatal, and it is possible that even with an apparently single unbranched thoracic duct the collateral circulation may in some way be set up. While, therefore, Keen's advice as to suturing the duct when practicable is to be followed, where this is impossible for any reason the surgeon may rationally employ packing and compression, even to the extent of the occlusion of the canal, with some hope of successful results.

In 8 out of 9 reported cases of operative injury to the thoracic duct, recovery followed compression, packing, or suture; and in the single fatal case death resulted from the shock of a severe operation.

[1] *N. Y. Med. Jour.*, 1894, vol. xix., p. 569.
[2] *Arch. für klin. Chirurg.*, 1893, vol. xxix., p. 443.
[3] Case reported by Keen.

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